AN INVESTIGATION OF DESTROYER MIDSHIP SECTION DESIGN WITH VARYING LONGITUDINAL AND WEB FRAME SPACING

by

ROBERT OLIVER DULIN, JR.

B.S., UNITED STATES NAVAL ACADEMY

(1961)

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE

DEGREES OF MASTER OF SCIENCE AND NAVAL ENGINEER

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

May, 1967

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ABSTRACT

AN INVESTIGATION OF DESTROYER MIDSHIP SECTION

DESIGN WITH VARYING LONGITUDINAL AND WEB FRAME SPACING

bу

Robert Oliver Dulin, Jr.

Submitted to the Department of Naval Architecture and Marine Engineering on May 19, 1967, in partial fulfillment of the requirements for the Master of Science degree in Naval Architecture and Marine Engineering and the Professional degree, Naval Engineer.

The attractive possibility of minimizing ordering, handling, and warehousing problems by employing uniform longitudinal scantlings and constant plating thicknesses throughout the midship section led to the decision to carry out an investigation of such a design methodology. The design technique proved to be feasible, but less economical than conventional techniques of midship section design.

A computer tool for the systematic variation of longitudinal intervals has been developed and is now ready to be applied to midship section design with varying structural materials and different plating thicknesses and longitudinal scantlings.

Thesis Supervisor: J. Harvey Evans

Title: Professor of Naval Architecture



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I. INTRODUCTION

"The quest for least weight, lowest cost, optimal ship structures has long been hampered by the lack of reliable quantitative data in adequate amount. And the problem has, so far, proven only partially susceptible to closed form solution. In no real sense, therefore, has it been possible to weigh the relative merits of new materials of construction, for example, or <u>variations of frame spacing</u>, different combinations of framing systems or alterations of principal dimensions (should they too be of interest)." [6] (Emphasis added)

The midship section design of longitudinally framed warships has long been carried out on the basis of a constant spacing of the longitudinal structural stiffeners, with varying stresses and loadings being accounted for by the variation of plating thicknesses and longitudinal scantlings.

This conventional procedure has resulted in the development of designs of adequate strength, but the goal of the optimum least weight, lowest cost ship structural design has proved to be an elusive one.

Current design techniques, although effective, add to the cost of ship construction by the price penalties involved in the procurement of a diversity of plates and shapes.



Similarly, parts handling and inventory control is complicated and rendered more difficult and expensive. These problems and deficiencies resulting from conventional midship section design procedures suggested the novel approach which is the subject of this investigation.

Fundamentally, in an evaluation of an extreme variation from current procedures, this modified design methodology generates a design with a uniform plating thickness throughout, with a uniform longitudinal scantling (exclusive of the keel) similarly selected. Variations in loading are compensated for by different intervals between longitudinals throughout the midship section.

In order to permit a reasonable inference as to the relative merits of this modified design methodology, the FORREST SHERMAN (DD-931) class destroyer midship section has been taken as a model for comparative purposes.



II. PROCEDURE

For purposes of consistency with the techniques used in the original design of the FORREST SHERMAN, the design procedured elucidated in [1], have been used throughout this investigation, modified as necessary. The same basic stress criteria have been used, with the maximum primary compressive stresses on DD-931 specified as design limiting values. As for the FORREST SHERMAN, high tensile steel (HTS) has been used throughout the midship section.

The calculations required for this investigation have been carried out almost exclusively by a series of computer programs and subroutines, explained in detail in the Appendix.

Input data, including the plating molded offsets, are generated for eventual use in the main design program, RUNSCORE, and the main costing program, COSTDATA. Existing plates and scantlings were used throughout the investigation in order to permit a realistic evaluation of costs and structural characteristics. Actual costing criteria in use at the Boston Naval Shipyard were employed in conjunction with current Federal parts costing information.

Once the input information has been determined, the detailed design process is carried out. First, given the transverse frame spacing and the minimum tolerable longitudinal



spacing, the least possible plating thickness is calculated, and the resultant permissible longitudinal separation computed.

This permissible separation is applied at the keel, thereby locating the longitudinal adjacent to the keel. The permissible span to the next longitudinal and the required longitudinal are then determined. This computation is repeated until the deck-shell intersection is reached. At this time, the spacings are reduced if necessary to assure the existence of at least the minimum permissible spacing between the last shell longitudinal and the deck edge.

The deck longitudinals are located in a like manner.

The arrangement is required to be symmetrical about the centerline, with either a longitudinal at the centerline or the centerline exactly at mid-span between longitudinals.

If necessary, the interval between the deck longitudinals is reduced.

After all the midship section longitudinals have been located, the required scantlings at each location are calculated. The heaviest of these is then selected for use throughout the midship section.

With the plating thickness selected, longitudinals located and scantlings determined, the overall midship section characteristics are calculated. The maximum primary compressive stresses at the keel and deck centerline are determined, using the hull girder bending moments that



were calculated for the FORREST SHERMAN.

Should either of the calculated stresses exceed the comparable values actually existing on the DD-931 as built, the plating thickness is increased and the entire cycle is repeated with larger longitudinal spacings inevitably resulting. If the stresses are acceptable, the calculation is terminated.

The costing procedure evaluates the expense, per foot length, of building the midship section. Most of the charges are based on an arbitrary cost of \$7.50 per man-hour (M-H) of work. This charge includes shippard overhead expenses. Government price data is used to determine the acquisition costs for structural materials.

The weight and cost of the modified design is then compared with similarly-calculated values for the DD-931 as built.



III. RESULTS

Two basic series of midship section design calculations were carried out by main program RUNSCORE. The first of these computed designs with the minimum acceptable interval between longitudinals fixed at 1.667 feet, while the transverse frame spacing varied from 6 to 8 to 10 feet. The second series calculated designs for a transverse frame spacing fixed at 8 feet with the interval between longitudinals stipulated to be a minimum of either 1.667, 2.000, or 2.333 feet.

Not surprisingly, the midship section designs developed with constant plating thicknesses and uniform longitudinal scantlings proved to be consistently heavier and, for less apparent reasons, which are discussed in the following section, more expensive to build.

The results of the calculations for different transverse frame intervals are presented in Table I, as well as
similar data for the FORREST SHERMAN as built. Figure I
shows a schematic plan of the DD-931 midship section as built,
while Figure II shows a schematic for the midship section
design resulting from a transverse frame spacing of 8 feet
with a minimum specified longitudinal interval of 1.667 feet.
Note the heavy plating, heavy longitudinals, and great in-



tervals between longitudinals in the new midship section design. Table I also provides detailed cost data for the three new designs as well as the original DD-931, using identical reference data for all four cases.

Detailed information as to the location of longitudinals and the intervals between longitudinals is provided in Table II, which delineates the designs developed by the first series of computations.

The second series of computer runs revealed this design methodology to be very insensitive to the specification of minimum tolerable intervals between longitudinals, with the exception of the minor effects caused by possible adjustments for the deck-shell intersection of the deck centerline criteria for longitudinal intervals. As a consequence, the designs for all intents and purposes were identical regarlless of the specified minimum intervals between longitudinals.



TABLE I

MIDSHIP SECTION DESIGNS
WEIGHT AND COST SUPMARIES

| DESIGN: 1 | Vew Study | New Study | New Study | DD-931 (As Built) |
|----------------------------------------------|------------------------------------|------------------------------------|-----------------------------------------------------|------------------------------------|
| FRM (Ft.) THL (In.) | 6.00 0.75 | 8.00 0.75 | 10.00 0.75 | 8.00 (Varies) |
| WEIGHTS (Pour | nds per fo | ot hull leng | th) | |
| TOTAL: | 4736.6 | 4716.7 | 4748.0 | 3591.0 |
| Plating Longithls. Tr. Framing | 3854.0 505.3 377.2 | 3854.0 505.3 357.4 | 3854.0 548.5 345.5 | 2724.5 509.1 357.4 |
| COSTS | (Per foo | t hull lengt | h) | |
| TOTAL: \$ | 1568.01 | \$ 1471.78 | \$ 1417.65 | \$ 1344.41 |
| Plating Longithls. Keel Tr. Framing | 464.97 66.30 27.56 404.96 | 466.61 66.30 27.56 303.72 | 464.97 70.20 27.56 242.98 | 336.98 70.50 27.56 303.72 |
| Pl. Welding Pl. Cutting Pl. Rolling | 298.64 2.02 23.40 | 301.33 2.70 23.40 | 298.6 ¹ + 2.02 23. ¹ +0 | 256.67 0.00 19.18 |
| L. Welding Fl. Cutting | 113.50 17.85 | 113.50 17.85 | 120.18 18.90 | 142.50 28.50 |
| Rigging | 148.80 | 148.80 | 148.80 | 148.80 |



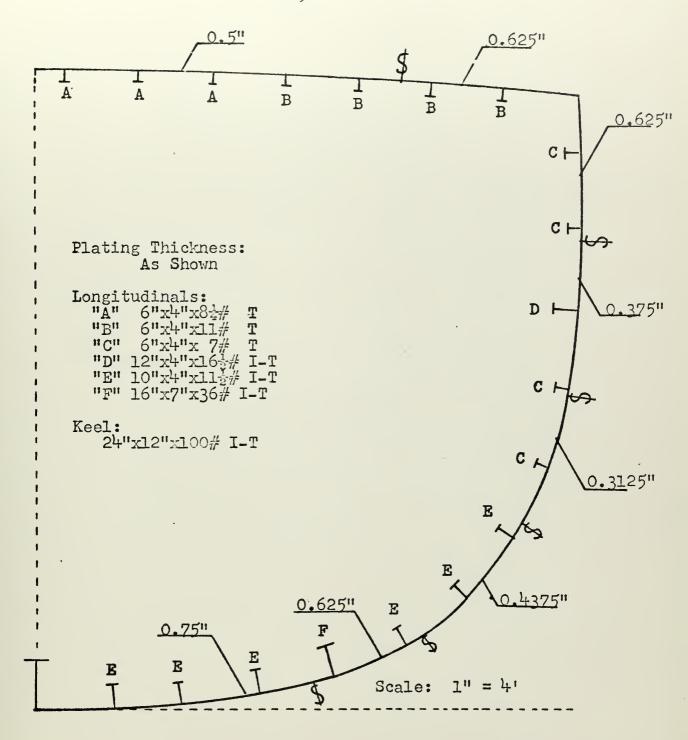


FIGURE I

THE ORIGINAL DD-931 MIDSHIP SECTION DESIGN [5]



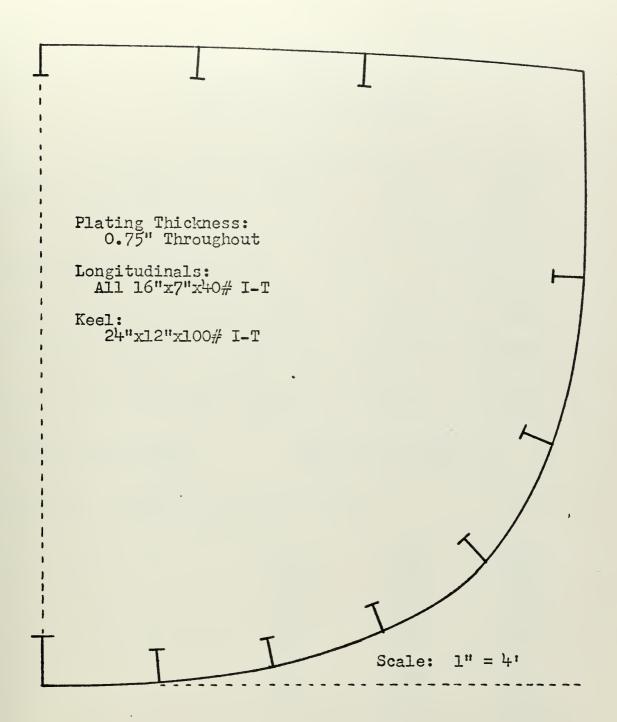


FIGURE II
MODIFIED DD-931 MIDSHIP SECTION DESIGN



TABLE II MIDSHIP SECTION DESIGNS STRUCTURAL DESCRIPTION

| Frame Spacing (Ft.) Plating Thickness (In.) | 6.00 0.75 | 8.00 0.75 | 10.00 | |
|-------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|--|
| | | | | |
| STRUCTURAL CHARACTERISTIC | CS | | | |
| Keel Stress (Tons/In.2) Deck Stress (Tons/In.2) | 7.43 4.58 | 7.43 4.59 | 7.43 4.45 | |
| Moment of Inertia I | 42,120 | 142,105 | 143,819 | |
| N. A. above Base Line (Ft.) | 14.26 | 14.25 | 14.46 | |
| Keel Longitudinal Other Longitudinals | | x 12" x 100# x 7" x 40# | I-T I-T | |
| INTERVALS BETWEEN LONGITUDINALS* (Feet) | | | | |
| Deck-Shell Intersection | 4.717 4.780 4.888 5.157 5.837 7.295 7.931 | 4.717 4.751 4.852 5.110 5.724 6.935 8.516 | 4.717 4.751 4.852 5.110 5.724 6.934 8.517 | |
| | 9.831 6.822 5.717** | 9.079 6.777 6.514** | 8.687 6.500 6.350 0.833*** | |

^{*}The first interval begins at the keel.

**A longitudinal lies on the deck centerline.

***The deck centerline lies midway between two longitudinals.



TABLE III

TYPICAL DESIGN SUMMARY*

| . , | |
|--------------------|--------------------------------------------------------------------------------|
| PLATE THICKNESS | TOTAL KEEL MOM. OF LONGITUDINALS WEIGHT STRESS INERTIA NO. SCANTLING |
| Inches | Pounds Tons/In. ² In. ² Ft. ² |
| | |
| 0.28125 | 2655.9 13.47 76,183 54 8x5.4x20 Stresses are excessive, design repeated. |
| 0.3125 | 2709.5 13.38 77,391 48 10x5.8x21 Stresses are excessive, design repeated. |
| 0.34375 | 2781.9 12.95 79,760 42 10x5.8x21 Stresses are excessive, design repeated. |
| 0.375 | 2898.4 12.43 83,690 39 10x5.8x21 Stresses are excessive, design repeated. |
| 0.4375 | 3131.4 11.45 91,387 33 10x5.8x21 Stresses are excessive, design repeated. |
| 0.500 | 3393.8 10.52 100,012 29 10x5.8x21 Stresses are excessive, design repeated. |
| 0.625 | 3918.8 9.03 117,352 23 12x 4 x16.5 Stresses are excessive, design repeated. |
| 0.750 | 4716.7 7.43 142,105 17 16x 7 x40 Design acceptable, calculations terminated. |

^{*}Main program RUNSCORE computation for transverse frame spacing of 8.0 feet, specified minimum longitudinal interval of 1.667 feet.



IV. CONCLUSIONS AND RECOMMENDATIONS

The midship section design of a longitudinally-framed warship with uniform longitudinal scantlings and constant plating thicknesses has been shown to be feasible.

Table I on page 8 vividly shows that the major contributor to the poor relative performance of this design methodology in terms of both weight and cost was the shell plating. Much of the added material near the neutral axis and on the deck (relative to the DD-931 as built) was very inefficiently applied, as is evident in the low stress levels existing in the deck structure of the new designs. Similarly, the cost of welding and fabrication of the shell plating was materially increased by the presence of the heavier plating throughout the girth of the midship section.

There appears to be a distinct reduction in cost per unit length as the interval between transverse frames is increased. This is apparently the consequence of the application of the cost of this framing to the overall structural cost. The cost per foot length of the transverse framing varies markedly as the interval between the frames is increased. Similarly, the weight of the transverse framing per foot hull length reduces as the interval between the frames is increased, although to a much smaller degree than the



cost varies.

No distinct trends in total weight per unit length were apparent in this investigation. The major factor leading to variations in weight was the number of longitudinals required, as both the selected plating thickness and longitudinal scantling were identical for all three cases examined in detail.

Unfortunately, no information was available to permit a reasonable estimation of the savings to be realized by the volume acquisition of identical structural members. This economy, along with the reduced handling and storage costs, should be incorporated in any such analysis as this, but is very doubtful that these savings would be of such magnitude as to offset the disparities existing between the new designs and the costs of consturction of the original DD-931 midship section design.

The traditional design concept of varying plating thicknesses and longitudinal scantlings is a sound one. This approach promises to be even more valuable when incorporated with the techniques developed in this investigation for the variation of the intervals between longitudinals. Furthermore, the use of different structural materials should be investigated in detail. Very frequently stability criteria dictate the plating thicknesses required when using high strength steels such as HY-80. The variation of longitudinal intervals would permit the use of much thinner plates in heavily stressed areas without the problems of plate stability



otherwise to be encountered. Appreciable weight economies should be realized from the superposition of the technique of variation of longitudinal intervals with the use of different structural materials while varying plating thicknesses and longitudinal scantlings.

The design of a midship section with a single plating thickness throughout and uniform longitudinal scantlings proved to be workable but less efficient than conventional techniques. The basic idea of varying longitudinal intervals is sound, and detailed studies of variations on this basic idea should be carried out.



APPENDIX



PROGRAM DOCUMENTATION

The structural and cost calculations for the midship section design were generated by a series of computer programs and subroutines, listed below, which are described and explained in detail on the following pages. A program listing, flow chart, and sample calculation accompanies the description of the operation of each program or subroutine.

All programs and subroutines were written in FORTRAN IV and were run on the IBM 360/65 computer.

Main Programs:

- A. RUNSCORE
- B. COSTDATA

Subroutines called by Main Programs.

- C. TSLECT
- D. HDWTR
- E. CSPACE
- F. CLONGL
- G. PMINER

Subordinate Programs used to generate input data for Nain Programs:

- H. SHDATA
- I. DKDATA
- J. PTLGTH
- K. WTSMOD
- L. TSHAPE
- M. COSTKL



A. MAIN PROGRAM RUNSCORE

1. DESCRIPTION

Introduction

Main program RUMSCORE carries out the design calculation for the midship section of DD-931, selecting one plating thickness and one longitudinal scantling (except for the keel) to be used throughout the structure. The basic computational methods described by St. Denis [1] are used, modified as necessary.

This program is not designed to optimize the characteristics of the midship section. The required plating thickness is selected, the spans between the various longitudinals are determined, and the required longitudinal scantlings are evaluated. Once the structural design has been completed, the net section characteristics are evaluated and the resultant primary compressive stresses are compared with the design criteria. Should the design be overstressed, the next greater available plating thickness is selected, and the entire cycle is repeated. RUNSCORE uses existing HTS plating thicknesses and longitudinal scantlings, as opposed to any idealized materials with a continuous range of available sizes. This, inevitably,



results in overdesigned structures in many cases.

After the input phase has been completed, subroutine TSLECT determines the minimum permissible plating thickness, dictated by the minimum tolerable longitudinal spacing specified as an input to the program. This subroutine also determines the greatest permissible interval between longitudinals for the stresses and hydrostatic loadings existing at the keel.

Beginning at the keel, the program "climbs" the girth of the midship section. The first longitudinal is located using the maximum permissible interval determined by subroutine TSLECT. Subroutine CLONGL then calculates the required longitudinal scantling for this location, and subroutine CSPACE evaluates the span to the next longitudinal, and the cycle is repeated. When the shelldeck intersection is reached, the program is designed to assure that the span to the intersection is at least the minimum permissible value. The distance to the intersection is compared with this minimum and, if necessary, the span is increased by reducing the spacings between the preceding longitudinals in the shell structure. This longitudinal relocation algorithm is so structured as to prevent the inadvertent reduction of longitudinal spans to less than the minimum tolerable value. Once the location of all longitudinal-plating intersections on the shell has been satisfactorily completed, the program proceeds to the



similar location of the deck lengitudinals.

The deck calculations are carried out in a manner identical to that used for the side shell. RUNSCORE is so structured that the midship section must be symmetrical, with a deck longitudinal on the centerline or the centerline exactly at mid-span between two deck longitudinals. As for the side shell, the spacings in all cases must be at least equal to the minimum permissible value. If necessary, provision is made for the systematic reduction of spans between longitudinals to insure that this is the case. Up to this point, the program has assumed that the longitudinals were of adequate strength, with no specific determination of scantlings.

With all longitudinal locations now determined, the required scantlings for each specific location are calculated, with the heaviest needed anywhere in the structure selected for use throughout the structure.

Criteria as to the minimum radius of gyration, stiffener strength, stiffener critical strength, and the stability of the stiffener-plating combination must all be satisfied.

With the plating thickness and longitudinal scantlings determined, subroutine PMINER is called to provide the information needed to calculate the contribution of the plating to the moment of inertia and cross-sectional area of the overall midship section. The effects of the



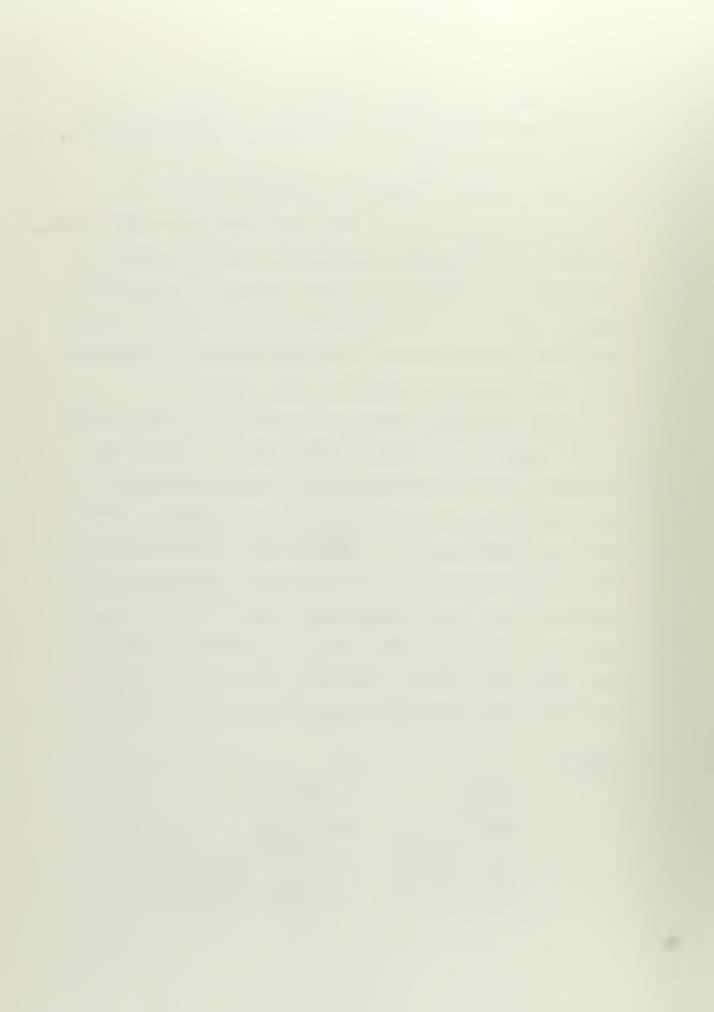
longitudinals are combined with this to determine the total cross-sectional area and moment of inertia for the entire midship section.

The structural weight of the midship section is evaluated in some detail. The total weight per foot length, including an approximate valuation of the contribution of the transverse framing to the net weight, is calculated in pounds and tons. The contributions of the plating, longitudinals, and transverse framing are similarly determined, but only in terms of pounds per foot length.

With the overall section characteristics fixed, the actual hogging and sagging bending moments used in the design of the DD-931 are employed in the calculation of the actual primary compressive stresses exerted in the keel and deck structure. Should either of these exceed the design limiting values, the plating thickness is increased to the next greater value, and the entire computation is repeated. This iterative process is carried out until both primary compressive stresses are determined to be less than the maximum permissible values.

Inputs

| Symbol | Meaning |
|---------------|-----------------------------------------|
| PTDATA(I,J,1) | Half breadth to point (I,J). (Feet) |
| PTDATA(I,J,2) | Height of point above base line. (Feet) |
| PTDATA(I,J,3) | Distance to next point on girth. (Feet) |



| Symbol | Meaning |
|---------------|--------------------------------------------------------------|
| STICRK | Maximum permissible stress at keel. (Tons/In.2) |
| STICRD | Maximum permissible stress at deck centerline. (Tons/In.2) |
| ST2EST | Estimated value of secondary stress. (Tons/In.2) |
| SGMULT/SGMYLD | Yield stress of the plating. (Tons/In.2) |
| A3HEEL | Specified maximum heel angle. (= 0.5236 radians) |
| Dl | Depth of hull. (= 26.231247 feet) |
| HLANDK | Specified design head of water above main deck. (= 4.0 feet) |
| HIDFL | Design full load draft. (= 14.5 feet) |
| XLGTNL(I,1) | Maximum moment of inertia of stiffener (I). (In. ") |
| XLGTNL(I,2) | Stiffener minimum moment of inertia. (In. +) |
| XLGTNL(1,3) | Stiffener area. (In. ²) |
| XLGTNL(I,4) | VCG of stiffener from the cut |
| XLGTWL(I,5) | flange. (In.) Stiffener overall depth. (In.) |
| W5BMIN | Minimum permissible longitudi- |
| FRM | nal spacing. (Feet) Transverse frame spacing. (Feet) |

Calculated Items

| Symbol | Meaning |
|--------------|------------------------------------------------------------------------|
| XLONGL(I,1) | Half breadth of intersection of plating with longitudi-nal (I). (Feet) |
| XLONGL(I,2) | Height above keel of plating- longitudinal intersection. (Feet) |
| XLONGL(I,3) | Half breadth of point preceding the intersection. (Feet) |
| XLONGL(I,1+) | Height above keel of point pre- ceding the intersection. (Feet) |



| <u>Symbol</u> | Meaning |
|------------------------|---------------------------------------------------------------------------------------------------------------|
| W5BACT | Tolerable longitudinal spacing for selected plating thickness. (Feet) |
| W5BPRC | Longitudinal span to longitudinal in question. (Feet) |
| W5BTOL | Permissible spacing to next longitudinal. (Feet) |
| SUMDST/DSTSUM/ DSUM | Sum of distances between points on girth. (Feet) |
| SUMCAL/SULDIF | Distance to point preceding plating-longitudinal intersection. (Feet) |
| DIFF | Distance from point at SUMCAL/ SUMDIF to the intersection. (Feet) |
| ILONGL | An identifying number for lon- gitudinals other than the keel. No. 1 adjacent to the keel. |
| ICOUNT | The value of ILONGL at deck- shell intersection. No longitudinal here. |
| SPAN(I) | Distance to longitudinal (I) from preceding longitudi- nal. (Feet) |
| BBDIST | Distance needed to be gained by reducing spans between shell longitudinals to permit W5BMIN distance |
| | from last shell longitudi- nal to deck intersection. (Feet) |
| STEP . | Increment the span between longitudinals is reduced. (Feet) |
| IDIFF | Number of spans to be reduced on deck to obtain desired span at centerline. |
| AAA | Effective width of plating. (In.) |
| FF | Moment of longitudinal-plating combination about outer |
| FFF | edge of the plating. (In.3) Total area of the longitudinal plating combination. (In.2) |



| Symbol | <u>Keaning</u> |
|-----------|--------------------------------------------------------------------------------------------------------------|
| CGCG(I) | Centroid of longitudinal - plating combination, in web axis. (In.) |
| XMINER(I) | Moment of inertia of longi- tudinal-plating combi- nation about CGCG(I). (In. †) |
| RGYR | Radius of gyration of lon- gitudinal-plating combi- nation. (In.) |
| EFSPAN | Effective span (supports fixed) for stiffener strength calculation . (Feet) |
| DVALUE | Flexural rigidity of plating. (Ton-In.) |
| STALL | Permissible sum of primary and secondary stresses. (Tons/In. ²) |
| ARM | Distance to outermost fiber of longitudinal-plating combination from CGCG(I). (Inches) |
| PRESS | Hydrostatic pressure at lon- gitudinal. (Tons/In.2) |
| BMOMNT | Maximum bending moment on the longitudinal-plating combination at mid-span. (Ton-In.) |
| STIEST | Estimated primary stress. (Tons/In.2) |
| ST2ALL | Allowable value of secondary stress. (Tons/In.2) |
| REQMOD | Required section modulus of plating-longitudinal combination. (In.3) |
| SMODAN(I) | Required section modulus for Iongitudinal (I)-plating combination at determined by subroutine CLONGL. (In.3) |
| BVALUE | Rigidity. (EI) (Ton-In.2) |
| BETA | Aspect ratio of plate. |
| GAMMA | Inertia factor. |
| DELTA | Area factor. |



| Symbol . | Meaning |
|-------------|--------------------------------------------------------------------------------------------------------------------------------|
| SUHTN | Intermediate value used in calculating critical strength of stiffened plating. (Tons/In.2) |
| BETAPL | Used in calculating critical strength of stiffened plating. (BETA ² + 1) |
| CRITST | Design stress criteria. (Tons/In.2) (1.25 x (STIEST + ST2EST)) |
| TOLSTR | Tolerable stress level de- termined by critical strength calculation. (Tons/In.2) |
| AREAPT | Total cross section area of half breadth plating. (In.2) |
| XLNGTL(1,I) | Characteristics of keel longitudinal. |
| XLNGTL(2,I) | Characteristics of other |
| SLOPE2(K) | longitudinals. Slope of the web of longi- |
| ZZZ | tudinal (K). Height of VCG of longitudinal above longitudinal-plating intersection. (Feet) |
| ZPOINT | Height of VCG of longitudinal above the base line. (Feet) |
| BASEMT(K) | Height of VCG of longitudinal above the base line. (Feet) K = 1 Keel K = 2,40 (LONGL 1,39) |
| BLMOM | Total moment about the base |
| MOMIN | line. (In. Feet) Total moment of inertia about the base line. (In. Feet2) |
| XINER | Moment of inertia of the mid- ship section about the |
| ATHL | neutral axis. (In. ² Feet ²) Plating thickness found to be insufficient, to be in- cremented. (Inches) |

Output

| Symbol | Meaning |
|--------|---------------------------------------------------------|
| WEIGHT | Weight contribution of the plating. (Pounds/Ft. length) |



| Symbol | Meaning |
|---------|------------------------------------------------------------------------------|
| ZNAXIS | Height of neutral axis of mid- ship section above base line. (Feet) |
| REQMIN | Required moment of inertia about original DD-931 neutral axis. (In. 2 Ft. 2) |
| ASTRSS | Actual primary compressive stress in keel. (Tons/In.2) |
| BSTRESS | Actual primary compressive stress in deck. (Tons/In.2) |
| WTOTLB | Total structural weight. (Pounds/ Ft. length) |
| WFRALE | Transverse frame weight. (Pounds/ Ft. length) |
| WTOTAL | Total weight. (Tons/Ft. length) |
| WLCNGL | Total longitudinal weight. (Pounds/Ft. length) |

Sample Input/Output (Refer to printout of typical computer run, following pages)

Fundamental Equations (Refer to program listing, following pages, and St. Denis [1])

THE FOLLOWING IS A REPRESENTATIVE SAMPLING OF EQUATIONS PARTICULARLY IMPORTANT TO MAIN PROGRAM RUNSCORE:

Longitudinal location

SUMDST = SUMDST + PTDATA(I,J,3)

SUMCAL = SUMDST - PTDATA(1,J,3)

DIFF = W5BPRC - SUNCAL

DIFF x (PTDATA(I,J+1,I)
- PTDATA(I,J,I)

 $XLONGL(ILONGL,1) = PTDATA(I,J,1) + \frac{-PTDATA(I,J,1)}{PTDATA(I,J,3)}$

XLONGL(ILONGL,3) = PTDATA(I,J,1)

Satisfy requirements as to minimum radius of gyration

AAA = lesser, 12. x SPAN(I) or 50. x THI

FF = $XLGTNL(J,3) \times (XLGTNL(J,4) + THI) + 0.5 \times AAA \times (THI²) +$



FFF = KLGTNG(J,3) + THL x AAA

CGCG(I) = FF / FFF

XMINER(I) = XLGTNL(J,1) + XLGTNL(J,3) x (XLGTNL(J,4) - CGCG(I))² + 0.08333 x AAA x THL³ + THL x AAA x (CGCG(I) -0.5 x THL)²

 $RGYR = \sqrt{\frac{XMINER(I)}{EFR}}$

Satisfy requirements as to stiffener strength

EFSPAN = 12. \times 0.577 \times FRM

DVALUE = $\frac{13392.857 \times \text{TH}^3}{10.8}$

BMOMNT = 216. x PRESS x SPAH(I) x FRE^2

REQMOD = BMOMNT / ST2ALL

BVALUE = 13392.857 x XMINER(I)

 $GAMMA = \frac{BVALUE}{12. \times SPAN(1) \times DVALUE}$

XLGTNL(J,3)
12. x SPAN(I) x THI DELTA =

SUMTN = $\frac{3.1416^2 \times \text{DVALUE}}{144. \times \text{THL} \times \text{SPAN}(1)^2}$

 $BETAPL = 1.0 + BETA^2$

 $CRITST = 1.25 \times (STIEST + ST2EST)$

TOLSTR = $\frac{\text{SUMTN } \times (\text{BETAPL}^2 + 4. \times \text{GAFMA})}{\text{BETA}^2 \times (1. + 4. \times \text{DELTA})}$

Calculate the total moment of inertia of the midship section

ADINER = XLNGTL(1,3) x BASENT(K)² +
XLNGTL(1,2)/144. + (XLNGTL(1,1) XLNGTL(1,2))² x 2. x | Arctan(SLOPE2(K)) |
| 144. x 3.1416

ZNAXIS x (BLMOM² - AREAPT x XMOMIN)



Add in the weight contribution of the main transverse frames

WTOTLB = 3.4 x AREAPT + (0.833 x (FRM - 8)/8))
FRM

Sample Calculation (Refer to program listing, flow chart, and printout of typical computer run, following pages)



```
DIMENSION XLUNGL(40,4), SPAN(40), SMODMN(40), XLGTNL(9,5), XLNGTL(2,5)
     1,CGCG(40),XMINER(40),SLOPE2(40),PTDATA(30,10,3),BASEMT(40)
C
C
      INPUT DATA AND INITIALIZE STORAGE VALUES
C
      W5BACT = 0.0
  954 FORMAT (*1
                      I
                                       PTDATA(I,J,l)
                                                        PTDATA(I,J,2)
    1 PIDATA(1, J, 3)')
  951 FORMAT (4X, I4, 4X, I4, 7X, 3(F10.6, 5X))
      WRITE (6, 954)
  901 FORMAT (23X, 4(2X, F10.6))
      DO 907 I = 1,29
      DO 907 J = 1,10
  907 READ (5,901) PTDATA(I,J,1), PTDATA(I,J,2),PTDATA(I,J,3)
      DO 903 I = 1, 40
      DO 903 J = 1, 4
  903 XLUNGL(I,J) = 0.0
      DATA XL1BP, SUMDST, ILONGL, R5GYRA, w5BTUL/407., 0., 1, 0., 0./
      I = 30
      J = 1
      READ (5,901) PTDATA(I,J,1), PTDATA(I,J,2), PTDATA(I,J,3)
      DO 910 J = 2, 10
      DO 910 K = 1, 3
  910 PTDATA(I, J, K) = 0.0
      DO 941 J = 1, 2
      DU 941 K = 1, 5
  941 XLNGTL(J,K) = 0.0
  900 FORMAT (5F16.7)
  915 FORMAT ('1 REQUIRED MOMENT OF INERTIA = 1, F20.6, 1 IN # 2 FT # 21)
  916 FORMAT ( *O ACTUAL MOMENT OF INERTIA = *, F20.6, * IN**2 F1**2*)
  917 FORMAT ('O MAX. TOLERABLE STICKK =',F10.7,' TONS PER SQ. INCH')
  918 FORMAT (*) ACTUAL STICRK = 1, F10.7, 1 TONS PER SQ. INCH!)
  919 FORMAT ('O MAX. TOLERABLE STICRD =',FI0.7,'TONS PER SQ. INCH')
  920 FORMAT ( °C
                 ACTUAL STICRD =',F10.7,' TUNS PER SQ. INCH')
  921 FORMAT ('O TOTAL WEIGHT =', F10.7,' TONS PER FOOT LENGTH')
 1921 FORMAT ('0
                       PLATING WEIGHT =', F15.7,' POUNDS PER FOOT LENGTH'
     1)
 1922 FORMAT (*
                       LONGITUDINAL WEIGHT =", F15.7, POUNDS PER FOUT LE
     INGTH')
 1923 FORMAT ( !
                       TRANSVERSE FRAME WEIGHT = 1, F15.7, 1 POUNDS PER FOUT
     1 LENGTH')
  922 FORMAT ('0
                  TOTAL WEIGHT =', F15.7,' POUNDS PER FOOT LENGTH')
                  NEUTRAL AXIS IS ',F10.7,' FEET ABOVE BASE LINE')
  923 FORMAT ('0
  924 FORMAT (*0
                      DESIGN IS ACCEPTABLE!)
                     SPAN(', I2, ') = ', F10.6)
  934 FURMAT (10
  933 FURMAT (*1
                     SPAN(*, 12, *) = *, F10.6)
  925 FORMAT ( '0
                       DESIGN REPEATED WITH THI INCREASED*)
                       DESIGN IS NOT POSSIBLE UNLESS THI IS GREATER THAN
  926 FORMAT ('0
```



C

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```
1 ONE INCH. 1)
928 FORMAT ('C SCANTLING ', 13, ' SELECTED -- CROSS-SECTION AREA IS', F!
   10.7, SQ. IN. AND WEB DEPTH IS ',F10.7,' INCHES.')
929 FORMAT('O KEEL HAS AN AREA OF', FIC. 7, 'SQ. IN. AND A WEB DEPTH OF
   1 ',F10.7,' INCHES.')
    D0950 I = 1, 30
    DO 950 J = 1, 10
950 WRITE(6,951) I,J,PTDATA(I,J,1),PTDATA(I,J,2),PTDATA(I,J,3)
    READ (5,900) STICRK, STICRD, STZEST, SGMULT, SGMYLD
955 FORMAT ('0 INTERIM THI =',F10.6,' AND W5BACT =',F10.6)
956 FORMAT (' I =',13,' J =',13,' SUMDST =',F10.6)
957 FORMAT ('0 SPAN(',12,') = ',F10.6,' I = ',12,' J = ',12)
958 FORMAT ( °C I = °, I3, ° HM = °, F10.6)
959 FORMAT ('0 XMINER(',12,') = F15.6)
960 FORMAT ('0 CGCG(',12,') = ', F10.6)
961 FURMAT ( 'C
                 LONGITUDINAL (', 12,') IS SELECTED')
962 FORMAT ('0 BASEMT(', I2,') = ',F10.6)
963 FORMAT ('0 SELECTED PLATING THICKNESS = ',F10.6,' INCHES. ')
    READ (5,900) A3HEEL, D1, H1AMDK, H1DFL
902 FURMAT (1H1,6X, ST1CRK ,9X, ST1CRD ,9X, ST2EST ,9X, SGMULT ,9X,
   1 'SGMYLD')
904 FORMAT (5(5X,F10.6))
905 FORMAT (5X, "N5BMIN = ", F10.6, " FRM = ", F10.6)
911 FORMAT (13,6(2X,F13.6))
912 FORMAT ('11',4X, Y
                                ',5X,' Z ',5X,' YPR ',
   1 5x, 'ZPR ',7x, 'SPAN(I)',7x, 'SMODMN(I)')
913 FORMAT (5F16.7)
964 FORMAT ('C I MAX. I. MIN. I. AREA
                                                                 VCG
  1 DEPTH!)
975 FORMAT (2X, I2, 2X,F11.6, 4(3X.F10.6))
    WRITE (6, 964)
    DO 914 I = 1, 9
    READ (5,913) XLGTNL(I,1), XLGTNL(I,2), XLGTNL(I,3), XLGTNL(I,4), XLGTN
   1L(I.5)
914 WRITE (6,975) I, XLGTNL(I,1), XLGTNL(I,2), XLGTNL(I,3), XLGTNL(I,4
   1), XLGTNL(I,5)
965 FORMAT( *O W5BACT = *, F10.6, * W5BPRC = *, F10.6, * W5BTOL = *, F10.6
   1)
966 FORMAT('0 Y = ',F10.6,' Z = ',F10.6,' YPR = ',F10.6,' ZPR = ',F10
   1.6)
967 FORMAT ('0 CLONGL OUTPUT = ',4(F10.6,5X))
    PROVIDE INPUT DATA TO CONTINUE CALCULATION INTERRUPTED IN PREVIOUS
    COMPUTER RUN. SOLUTION UP TO THIS TIME INDICATED FURTHER INCREMENTS
    IN PLATING THICKNESS WERE NECESSARY.
500 READ (5, 900) N5BMIN, FRM
    IF (W5BMIN .GT. 9.99) GU TU 420
```



```
W5BACT = 0.0
  400 WRITE (6, 9J2)
      SUMDST = 0.0
      ILONGL = 1
      W5BTOL = 0.0
      IF (W5BACT .GT. 0.0) GU TU 668
C
С
      DETERMINE PLATING THICKNESS
      CALL TSLECT (W5BMIN, STICRK, STZEST, SGMULT, FRM, TH1, W5BACT)
      GO TO 667
  668 W5BACT = TH1 * W5BACT / ATH1
  667 DU 940 J = 1, 40
      SPAN(J) = 0.0
      SMODMN(J) = 0.0
      CGCG(J) = 0.0
      XMINER(J) = 0.0
      SLOPE2(J) = 0.0
  940 \text{ BASEMT}(J) = 0.0
      D0 9940 J = 1, 40
      DO 9940 K = 1, 4
 9940 XLONGL(J,K) = 0.0
      WRITE (6,904) STICRK, STICRD, STZEST, SGMULT, SGMYLD -
      WRITE (6, 905) W5BMIN, FRM
      WRITE (6, 955) TH1, W53ACT
      W5BPRC = W5BACT
      WRITE (6,965) W5BACT, W5BPRC, W5BTUL
CCC
      DETERMINE ACCEPTABLE LONGITUDINAL SPACING FOR BOTH DECK AND SIDE
      SHELL LONGITUDINALS.
  226 DO 200 I - 1, 30
      DO 200 J = 1, 10
      IF (ILONGL .GT. 1) GO TO 333
      W5BPRC = W5BACT
      GO TO 115
  333 W5BPRC = W5BTOL
  115 SUMDST = SUMDST + PTDATA (I, J, 3)
      WRITE (6, 956) I, J, SUMDST
      IF (I .EQ. 30) GO TO 225
      IF (I .EQ. 19) GO TO 205
      GD TO 207
  205 IF (J .EQ. 10) GO TO 204
  207 IF ((SUMDST - W5BPRC) .GT. 0.0) GO TO 201
      GO TO 200
  201 SUMCAL = SUMDST - PTDATA(I, J, 3)
      DIFF = N5BPRC - SUMCAL
C
```



```
LOCATE THE LONGITUDINALS
      IF (J .EQ. 10) GO TO 202
      XLONGL(ILONGL,1) = PIDATA(I,J,1) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I,J+1,1) - PTDATA(I,J,1))
      XLONGL(ILONGL,2) = PTDATA(I,J,2) + (DIFF/PTDATA(I,J,3)) *
     1 (PIDATA(i, J+1, 2) - PIDATA(I, J, 2))
      XLONGL(ILONGL, 3) = PTDATA(I, J, 1)
      XLONGL(ILONGL, 4) = PTDATA(I, J, 2)
      SUMDST = SUMDST - W58PRC
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),X
     1LONGL(ILONGL,4)
      GO TO 203
  202 XLUNGL(ILONGL,1) = PTDATA(I,J,1) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I+1,1,1) - PTDATA(I,J,1))
      XLONGL(ILONGL.2) = PTDATA(I.J.2) + (DIFF/PTDATA(I.J.3)) *
     1 (PTDATA(I+1,1,2) - PTDATA(I,J,2))
      XLONGL(ILONGL,3) = PTDATA(I,J,1)
      XLONGL(ILONGL, 4) = PTDATA(I, J, 2)
      SUMDST = SUMDST - W5BPRC
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),X
     1LONGL(ILONGL,4)
C
C
      CALCULATE R5GYRA AND
                                      REQUIRED FOR LONGITUDINALS
                              SMODMN
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
  203 \text{ AAA} = R5GYRA
      CALL CLONGL(STICRK, STICRD, STZEST, SGMULT, FRM, TH1, W5BPRC,
     1 R5GYRA, SMODMN(ILONGL), XLONGL(ILONGL, 1), XLONGL(ILONGL, 2))
      WRITE (6, 967) R5GYRA, SMODMN(ILONGL), XLONGL(ILONGL, 1), XLONGL(ILUNG
     11,21
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
      IF (R5GYRA .GT. AAA) GO TO 210
      R5GYRA = AAA
CC
      DETERMINE LONGITUDINAL SPACING.
  210 CALL CSPACE (STICRK, STICRD, STZEST, SGMULT, FRM, THI,
     1 XLONGL(ILONGL,1),XLONGL(ILONGL,2),W5BPRC,W5BTOL)
      SPAN(ILUNGL) = W5BPRC
      WRITE (6, 957) ILONGL, SPAN(ILONGL), I, J
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
      ILONGL = ILONGL + I
      GO TO 200
      ADJUST FOR DECK-SHELL INTERSECTION.
  204 ICOUNT = ILUNGL
```



C C

```
IF (SUMDST .LT. W58MIN) GO TO 208
    SPAN (ILUNGL) = SUMDST
    WRITE (6, 957) ILONGL, SPAN(ILONGL), I, J
    SUMDST = 0.0
    XLONGL (ILONGL, 1) = PIDATA(20, 1, 1)
    XLONGL (ILONGL, 2) = PTDATA(20, 1, 2)
    XLONGL (ILONGL, 3) = PTDATA(20, 1, 1)
    XLONGL (ILONGL, 4) = PTDATA(20, 1, 2)
    WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),
   1 XLONGL(ILONGL, 4)
    ILUNGL = ILUNGL + 1
    GU TU 200
208 XX = ILONGL - 1
    BBDIST = W5BMIN - SUMDST
    STEP = BBDIST / XX
214 JJ = 1
    IF ((SPAN(1) - W5BMIN) .GT. STEP) GO TO 216
    ADJUST SPACING BY REDUCING THE SPAN.
    DO 98 JAJA=1, ILONGL
    CC = SPAN(JAJA) - W5BMIN
    BBDIST = BBDIST - CC
    IF (BBDIST .LT. 0.0) GO TO 97
98 SPAN (JAJA) = W58MIN
    WRITE (6, 957) JAJA, SPAN(JAJA), I, J
    IF (JAJA .EQ. ILONGL) GO TO 99
97 SPAN (JAJA) = SPAN (JAJA) - CC - BBDIST
    WRITE (6, 957) JAJA, SPAN(JAJA), I, J
99 STEP = 0.0
216
   DSTSUM = 0.0
999 DO 215 IA = 1, 19
    DO 215 JA = 1, 10
    DSTSUM = DSTSUM + PTDATA (IA, JA, 3)
    IF ((10*IA + JA) .EQ. 200) GU TO 110
    IF((SPAN(JJ) - DSTSUM) .LT. 0.0) GO TO 107
    GO TO 215
107 \text{ SPAN(JJ)} = \text{SPAN(JJ)} - \text{STEP}
    SUMDIF = DSTSUM - PTDATA(IA, JA, 3)
    DIFF = SPAN(JJ) - SUMDIF
    WRITE (6, 957) JJ, SPAN(JJ), IA, JA
    IF (SPAN(JJ) .GT. 0.0) GO TO 127
    SPAN(JJ) = 0.0
    WRITE (6, 957) JJ, SPAN(JJ), IA, JA
    GO TO 110
127 IF (JA .EQ. 10) GO TO 108
    XLONGL(JJ,1) = PTDATA(IA,JA,1) + (DIFF /
   1 PTDATA (IA,JA,3)) * (PTDATA(IA,JA+1,1) - PTDATA(IA,JA,1))
```



826 WRITE (6,957) IA, SPAN(IA), II, JJ

```
XLONGL(JJ,2) = PTDATA(IA,JA,2) + (DIFF / PTDATA(IA,JA,3)) * (PTDATA(IA,JA+1,2) - PTDATA(IA,JA,2))
      XLONGL(JJ,3) = PTOATA (IA, JA, I)
      XLONGL(JJ,4) = PTDATA (IA, JA, 2)
      WRITE(6,966)XLUNGL(JJ,1),XLUNGL(JJ,2),XLUNGL(JJ,3),XLUNGL(JJ,4)
    DSTSUM = DSTSUM - SPAN(JJ)
      JJ = JJ + 1
      GO TO 215
  108 XLONGL(JJ,1) = PTDATA(IA,JA,1) + (DIFF
     1 PTDATA(IA,JA,3)) * (PTDATA(IA+1,1,1) - PTDATA(IA,JA,1))
                         PIDATA(IA, JA, 2) + ( DIFF /
      XLONGL(JJ,2) =
     1 PIDATA(IA, JA, 3)) \star (PIDATA(IA+1,1,2) - PIDATA(IA, JA,2))
      XLONGL(JJ,3) = PTDATA(IA,JA,1)
      XLONGL(JJ,4) = PTDATA(IA,JA,2)
      WRITE (6, 966) XLONGL(JJ,1), XLONGL(JJ,2), XLONGL(JJ,3), XLONGL(JJ,4)
      DSTSUM = DSTSUM - SPAN(JJ)
      JJ = JJ + 1
      GO TO 215
  110 XLONGL(JJ,1) = PTDATA (20,1,1)
      XLONGL(JJ,2) = PTDATA(20,1,2)
      XLONGL(JJ,3) = PTDATA (20,1,1)
      XLONGL(JJ,4) = PIDATA (20, 1, 2)
      SPAN(ILUNGL) = W5BMIN
      WRITE (6, 966) XLONGL(JJ,1),XLONGL(JJ,2),XLONGL(JJ,3),XLONGL(JJ,4)
      WRITE (6, 957) JJ, SPAN(JJ), IA, JA
      ILONGL = ILONGL + 1
      SUMDST = 0.0
      GO TO 200
  215 CONTINUE
C
C
      ADJUST DECK LONGITUDINAL SPACING TO FACILITATE SYMMETRY RELATIVE
C
      TO THE CENTER LINE.
  225 IF (((0.5 * W5BMIN) - SUMDST) .GT. 0.0) GO TO 801
      GO TO 220
C
C
      DECREASE SPAN TO OTHER DECK LONGITUDINALS TO PERMIT CENTERING SPAN
      ON THE CENTERLINE.
  801 IDIFF = ILONGL - ICOUNT - 1
      XDIFF = IDIFF
      SIEP = (0.5 * W5BMIN - SUMDST) / XDIFF
      SPAN(ILONGL) = 0.5 * W5BMIN
      ILUNGL = ILONGL - 1
      IRKED = ICOUNT + 1
      DO 826 IA = IRKED, ILONGL, 1
      SPAN(IA) = SPAN(IA) - STEP
```



C

С

```
ILUNGL = ILUNGL + 1
    IA = ICOUNT > 1
   00\ 227\ II = 20, 29
   DO 227 JJ = 1, 10
   DSUM = DSUM + PTDATA(II,JJ,3)
    IF ((SPAN(IA) - DSUM) .LT. 0.0) GO TO 228
   GO TO 227
228 IF (JJ .EQ. 10) GO TO 229
    SUMDIF = DSUM - PTDATA(II,JJ,3)
   DIFF = SPAN(IA) - SUMDIF
    XLONGL (IA, 1) = PTDATA (II, JJ, 1) + ( DIFF /
   1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,1) - PTDATA(II,JJ,1))
   XLONGL (IA, 2) = PFDATA (II, JJ, 2) + (DIFF /
   1 PTDATA(II, JJ, 3)) * (PTDATA(II, JJ+1, 2) - PTDATA(II, JJ, 2))
   XLONGL(IA,3) = PTDATA(II,JJ,1)
    XLONGL(IA,4) = PTDATA(II,JJ,2)
    WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
   DSUM = DSUM - SPAN(IA)
    IA = IA + 1
   GO TO 227
229 SUMDIF = DSUM - PTDATA (II, JJ, 3)
    DIFF = SPAN(IA) - SUMDIF
   XLUNGL (IA, 1) = PTDATA (II, JJ, 1) + ( DIFF · /
   1 PTDATA(II, JJ, 3)) * (PTDATA(II+1,1,1) - PTDATA(II, JJ,1))
   XLONGL (IA, 2) = PTDATA (II, JJ, 2) + ( DIFF /
   1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,2) - PTDATA(II,JJ,2))
    XLONGL(IA,3) = PTDATA(II,JJ,1)
   XLONGL(IA,4) = PTDATA(II,JJ,2)
    WRITE(6,966)xLONGL(IA,1), XLONGL(IA,2), XLONGL(IA,3), XLONGL(IA,4)
    DSUM = DSUM - SPAN(IA)
    IA = IA + 1
227 CONTINUE
   GO TO 300
220 IF (SUMDST .GT. W5BMIN) GO TO 221
    DECREASE SPANS TO OTHER DECK LUNGITUDINALS TO PERMIT PLACING A
    LONGITUDINAL ON THE DECK CENTERLINE.
    IF (SUMDST .LT. 0.5*W5BTUL) GO TO 520
    BBDIST = W5BMIN - SUMDST
    IA = ILONGL - ICOUNT - 1
    XIA = IA
    SPAN(ILONGL) = W5BMIN
    STEP = BBDIST / XIA
    ICOUNT = ICUUNT + 1
    DO 230 IAI = ICUUNT, ILONGL
230 SPAN (IAI) = SPAN (IAI) - STEP
    ICOUNT = ICOUNT - 1
```



```
WRITE (6, 957) IAI, SPAN(IAI), II, JJ
    IA = ICOUNT
   DO 237 II = 20, 29
   00 \ 237 \ JJ = 1, 10
   DSUM = DSUM + PTDATA(II, JJ, 3)
   IF ((SPAN(IA) + DSUM) .LT. 0.0) GO TO 238
   GO TO 237
238 IF (JJ .EQ. 10) GO TO 239
    SUMDIF = DSUM - PIDATA (II, JJ, 3)
   DIFF = SPAN(IA) - SUMDIF
   XLONGL (IA, 1) = PTDATA (II, JJ, 1) + ( DIFF /
   1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,1) - PTDATA(II,JJ,1))
   XLONGL (IA, 2) = PTDATA (II, JJ, 2) + ( DIFF /
   1. PTDATA(II, JJ, 3)) * (PTDATA(II, JJ+1, 2) - PTDATA(II, JJ, 2))
   XLONGL(IA,3) = PTDATA(II,JJ,1)
   XLONGL(IA,4) = PTDATA(II,JJ,2)
   WRITE(6,966)XLONGL(IA,1), XLONGL(IA,2), XLONGL(IA,3), XLONGL(IA,4)
   DSUM = DSUM - SPAN(IA)
    IA = IA + 1
   GO TO 237
239 SUMDIF = DSUM - PTDATA (II, JJ, 3)
   DIFF = SPAN(IA) - SUMDIF
   XLONGL (IA, 1) = PTDATA (II, JJ, 1) + ( DIFF /
   1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,1) - PTDATA(II,JJ,1))
   XLONGL (IA, 2) = PTDATA (II, JJ, 2) + (DIFF /
   1 PIDATA(II, JJ, 3)) * (PIDATA(II+1,1,2) - PIDATA(II, JJ, 2))
   XLONGL(IA.3) = PTDATA(II.JJ.1)
    XLONGL(IA,4) = PTDATA(II,JJ,2)
   WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
    DSUM = DSUM - SPAN(IA)
    IA = IA + 1
237 CONTINUE
    GO TO 300
    SPAN GREATER THAN W5BMIN, PLACE LONGITUDINAL ON THE CENTERLINE.
221 SPAN(ILONGL) = SUMDST
    XLONGL(ILONGL,1) = PTDATA(30,1, 1)
    XLONGL(ILUNGL,2) = PTDATA(30, 1, 2)
    XLONGL(ILONGL,3) = PTDATA(30,1, 1)
    XLONGL(ILONGL,4) = PTDATA(30, 1, 2)
    WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),
   1 XLONGL(ILONGL, 4)
    GO TO 300
    CURRENT LONGITUDINAL PLACEMENT OK. CENTER SPAN ON CENTERLINE.
520 SPAN(ILUNGL) = SUMDST
```



```
GO TO 300
  200 CONTINUE
C
C
      CALCULATE THE REQUIRED LUNGITUDINAL SCANTLING.
  300 \ DO \ 310 \ I = 1, 5
  310 XLNGTL(1,I) = XLGTNL(9,I)
      WRITE (6, 912)
      D0 \ 206 \ III = 2, 40
      IF (SPAN(III) .GT. 0.0) GD TO 206
      SPAN(III) = 0.0
      IF (SPAN(III - 1) .GT. 0.0) GO TO 206
      XLDNGL(III,1) = 0.0
      XLONGL(III,2) = 0.0
      XLDNGL(III,3) = 0.0
      XLONGL(III,4) = 0.0
  206 WRITE(6,911) III, XLONGL(III,1), XLONGL(III,2), XLONGL(III,3),
     1 XLONGL(III,4), SPAN(III), SMODMN(III)
C
C
      SATISFY REQUIREMENTS AS TO MINIMUM RADIUS OF GYRATION.
C
      J = 1
      D0 320 I = 1, 40
      IF (SPAN(I) .EQ. 0.0) GO TO 323
      IF (XLONGL(I,2) .EQ. 0.0) GO TO 323
      IF (12.0*SPAN(I) .GT. 50.*TH1) GO TO 322
      AAA = 12.0 * SPAN(I)
      GO TO 321
  322 AAA = 50. *TH1
  321 FF = (XLGINL(J,4) + TH1) * XLCINL(J,3) + 0.5 * AAA * (TH1**2)
      FFF = XLGTNL(J,3) + TH1 * AAA
      CGCG(I) = FF/FFF
      WRITE (6, 960) I, CGCG(I)
      XMINER(I) = XLGTNL(J,1) + XLGTNL(J,3)*((XLGTNL(J,4)-CGCG(I))**2) +
     1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
      RGYR = SQRT (XMINER(I) / FFF)
      WRITE (6, 961) J
      IF(R5GYRA .LT. RGYR) GO TO 320
      J = J + 1
      GO TO 321
  320 CONTINUE
C
      SATISFY REQUIREMENTS AS TO STIFFENER STRENGTH.
  323 EFSPAN = 0.577 * FRM * 12.0
      DVALUE = (13392.857 * (TH1**3)) / 10.8
      STALL = 38000. / 2240.
      DO 324 I = 1, 40
```



```
IF (SPAN(I) .EQ. 0.0) GU TO 453
     IF (XLONGL(I,2) .EQ. 0.0) GO TO 453
 329 IF(((XLGTNL(J,5) + TH1) - CGCG(I)) .LT. CGCG(I)) GO TO 325
     ARM = CGCG(I)
     GO TO 326
 325 \text{ ARM} = \text{XLGTNL}(J,5) + \text{THI} - \text{CGCG}(I)
326 IF (12.0*SPAN(I) .GT. 50.*TH1) GD TU 327
     AAA = 12.0 * SPAN(I)
     GU TO 328
\cdot 327 \text{ AAA} = 50.0 * \text{ TH1}
 328 CALL HDWTR(A3HEEL, XLONGL(I, I), D1, H1AMDK, H1DFL, NBELTS, XL1BP,
    1 XLONGL(I,2),H.4)
     WRITE (6, 958) I, HM
     PRESS = 0.445 * HM/2240.
      BMUMNT = 216. * PRESS * SPAN(I) * FRM**2
     STIEST = 7.93 * ABS(XLONGL(1,2)-((7.93/13.93)*26.23125))
     STEALL = STALL - STIEST
     REQMOD = BMOMNT / ST2ALL
     XMINER(I) = XLGTNL(J,1) + XLGTNL(J,3) * ((XLGTNL(J,4) - CGCG(I)) * * 2) +
    1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
     WRITE (6, 961) J
     IF((XMINER(I)/ARM).LT.SMODMN(I)) GO TO 1324
     IF ((XMINER(I)/ARM) .GT. REQMOD) GO TO 324
1324 J = J + 1
     WRITE (6, 961) J
     GO TO 329
 324 CONTINUE
     SATISFY REQUIREMENTS AS TO STIFFENER CRITICAL STRENGTH.
453 DD 330 I = 1, 40
     IF (SPAN(I) .EQ. 0.0) GO TO 451
     IF (XLONGL(I,2) .EQ. 0.0) GU TO 451
336 IF (12.*SPAN(I) .GT. 50.*TH1) GO TO 337
     AAA = 12.0 * SPAN(I)
     GO TO 338
337 \text{ AAA} = 50.0 * TH1
 338 XMINER(I)=XLGTNL(J,1)+XLGTNL(J,3)*{(XLGTNL(J,4)-CGCG(I))**2) +
    1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
     BVALUE = 13392.857 * XMINER(I)
     BETA = FRM / SPAN(I)
     GAMMA = BVALUE / (SPAN(I) * 12. * DVALUE)
     DELTA = XLGTNL(J,3) / (12.0 * SPAN(I) * TH1)
     SUMTN = ((3.1416**2)*DVALUE)/(144. * TH1 * SPAN(I)**2)
     BETAPL = 1.0 + BETA**2
     ST1EST = 7.93* ABS(XLONGL(I,2)-((7.93/13.93)*26.23125))
     CRITST = 1.25 * (STIEST + STZEST)
     TOLSTR = SUMTN * (BETAPL**2 + 4.0*GAMMA)/((BETA**2)*(1.0 +
```



```
1 4.0 * DELTA))
     WRITE (6, 959) I, XMINER(I)
      IF (TOLSTR .GT. CRITST) GO TO 330
      J = J + I
      WRITE (6, 961) J
      GD TO 336
  330 CONTINUE
  451 WRITE (6, 961) J
C
C
     CALCULATE THE TOTAL MOMENT OF INERTIA OF THE MIDSHIP SECTION.
C
     CALL PMINER(TH1, BLMOM, AREAPT, XMOMIN, XINER)
      WEIGHT = 6.8 * AREAPT
      DO 335 I = 1, 5
  335 XLNGTL(2,I) = XLGTNL(J,I)
      K = 1
      SLOPE2(K) = (XLONGL(K,3)-XLONGL(K,1))/(XLONGL(K,2)-XLONGL(K,4))
      ZZZ = XLNGTL(1,4)*(-SLOPE2(K))/(12.*SQRT(1.+(SLOPE2(K)**2)))
      ZPOINT = XLONGL(K,2) + ZZZ
      BASEMT(K) = ZPOINT
      WRITE (6, 962) K, BASEMT(K)
      DO 340 K = 2, 40
      IF (K .GT. ILONGL) GO TO 810
      IF (XLONGL(K,2) .EQ. 0.0) GO TO 810
     IF (K .LT. ICOUNT) GO TO 1811
      IF (K .GT. ICOUNT) GO TO 1811
      BASEMT(K) = 0.0
     GB TB 340
 1811 CONTINUE
      SLOPE2(K) = (XLONGL(K,3)-XLONCL(K,1))/(XLONGL(K,2)-XLONGL(K,4))
      ZZZ = XLNGTL(2,4)*(-SLOPE2(K))/(12.*SQRT(1.+(SLOPE2(K)**2));
      ZPOINT = XLONGL(K,2) + ZZZ
      BASEMT(K) = ZPUINT
  340 WRITE(6, 962) K, BASEMI(K)
  810 AREAPT = 2.0 * AREAPT
      BLMOM = BLMOM * 2.0
      XMOMIN = 2.0 * XMOMIN
      K = 1
      ADINER = XLNGTL(1,3)*BASEMT(K)**2 + XLNGTL(1,2)/144. + (XLNGTL(1,1))
     1) - XLNGTL(1,2))*2.*ABS(ATAN(SLOPE2(K))/(144.*3.1416))
      XMOMIN = XMOMIN + ADINER
      BLMOM = BLMOM + BASEMT(K) *XLNGTL(1,3)
      AREAPT = AREAPT + XLNGTL(1,3)
      00\ 350\ K = 2, 40
      IF (XLUNGL(K,2) .EQ. 0.0) GO TO 351
      IF (K .GT. ILONGL) GO TO 351
      1) - XLNGTL(2,2))*2.*ABS(ATAN(SLOPE2(K))/(144.*3.1416))
```



C

```
MAIN
    IF (K .EQ. ILONGL) GD TO 352
    IF (K .EQ. 136UNT) GO TO 350
353 XMOMIN = XMOMIN + 2.0 * ADINER
    BLHOM = SLMOM + 2.0 * BASEMT(K) *XLNGTL(2,3)
    AREAPT = AREAPT + 2.0 * XLNGTL(2.3)
    GO TO 350
352 IF (XLUNGL(ILONGL,1) .GT. 0.0) GO TO 353
    XMOMIN = XMOMIN + ADINER
    BLMOM = BLMOM + BASEMT(K) * XLNGTL(2, 3)
    AREAPT = AREAPT + XLNGTL(2, 3)
350 CONTINUE
351 ZNAXIS = BLMUM / AREAPT
    XINER = ABS (ZNAXIS*((BLMOM**2) - AREAPT*XMOMIN)/BLMOM)
    REQMIN = 74100. * 26.231247 / 13.93
    DD 807 KK = 1, 40
    IF (SPAN(KK) .GT. 0.0) GO TO 807
    SPAN(KK) = 0.0
807 CUNTINUE
    IR = 1
    WRITE (6, 933) IR, SPAN(IR)
    DO 600 IR= 2, 40
600 WRITE (6, 934) IR, SPAN(IR)
804 WRITE(6,912)
    DO 806 KK= 1, 40
806 WRITE(6,911) KK, XLONGL(KK,1), XLONGL(KK,2), XLONGL(KK,3),
   1 XLONGL(KK, 4), SPAN(KK), SMODMN(KK)
    WRITE (6,915) REQMIN
    WRITE (6,916) XINER
    WRITE (6,917) STICRK
    ASTRSS = 74100. * ZNAXIS / XINER
    WRITE (5,918) ASTRSS
    WRITE (6,919) STICRD
    BSTRSS = 54400. * (26.231247 - ZNAXIS) / XINER
    WRITE (6, 920) BSTRSS
    ADD IN THE WEIGHT CONTRIBUTION OF THE MAIN TRANSVERSE FRAMES.
    WIOTLB = AREAPT * 3.4 + 2859.*(1.0 + (0.8333*(FRM-8.)/8.)) /
   1 (FRM)
    WFRAME = WTOTLB - 3.4 * AREAPT
    WTOTAL = WTOTLB / 2240.
    WRITE (6,921) WTOTAL
    WRITE (6,922) WTOTLB
    WRITE (6, 1921) WEIGHT
```

WLONGL = WTOTLB - WEIGHT - WFRAME

WRITE (6, 1922) WLONGL WRITE (6,1923) WFRAME WRITE (6, 923) ZNAXIS



417 TH1 = 0.75 GO TO 400

420 STOP END

```
WRITE (6,928) J.XLNGTL(2,3),XLNGTL(2,5) WRITE (6,929) ALNGTL(1,3),XLNGTL(1,5)
    WRITE (6, 963) THI
    IF (STICRK .LT. ASTRSS) GO TO 421
    IF (STICRD .GT. BSTRSS) GO TO 500
421 \text{ ATH1} = \text{TH1}
    WRITE (6, 925)
    IF (TH1 - 0.5) 401, 402, 403
402 TH1 = 0.625
    GO TU 400
403 IF (TH1 - 0.875) 404, 405, 406
405 \text{ TH1} = 0.9375
    GO TO 400
406 IF(TH1 - 0.9375) 405,407,408
407 TH1 = 1.0
    GO TO 400
408 WRITE (6, 926)
    GO TO 420
401 IF(TH1 - 0.3125) 409, 410, 411
410 \text{ TH1} = 0.34375
    GU TU 400
409 IF (TH1 - 0.28125) 412, 413, 410
413 \text{ TH1} = 0.3125
    GO TO 400
412 TH1 = 0.28125
    GO TO 400
411 IF (THI - C.375) 414, 415, 416
415 \text{ TH1} = 0.4375
    GO TO 400
414 \text{ TH1} = 0.375
    GO TO 400
416 \text{ TH1} = 0.500
    GO TO 400
404 IF(TH1 - 0.75) 417, 418, 405
418 \text{ TH1} = 0.875
    GO TO 400
```



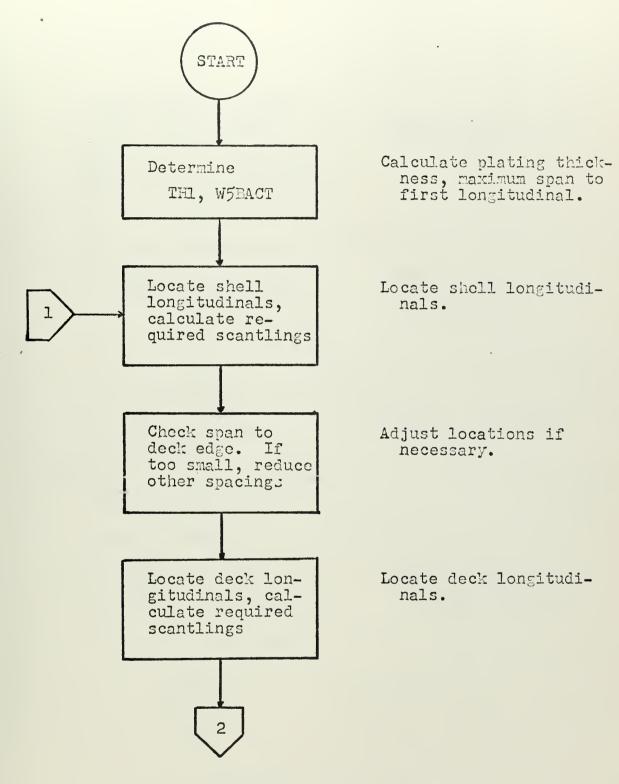


FIGURE III

MAIN PROGRAM RUNSCORE FLCW CHART



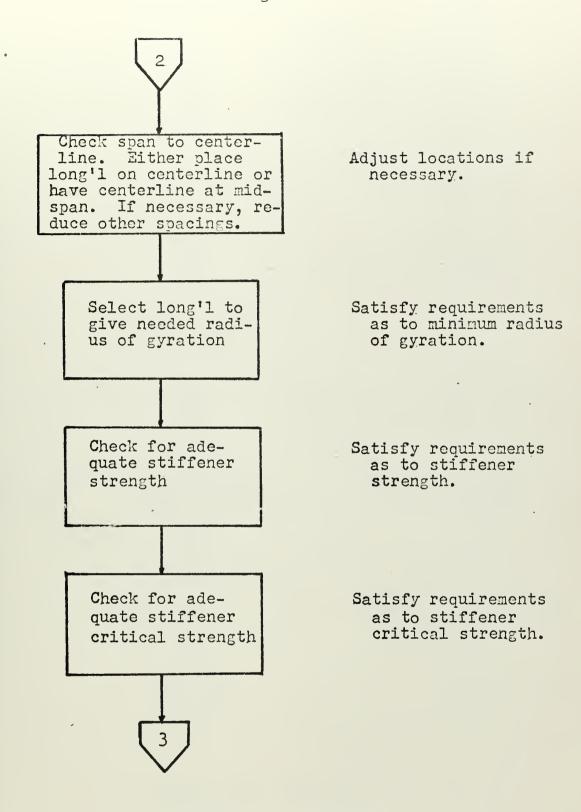
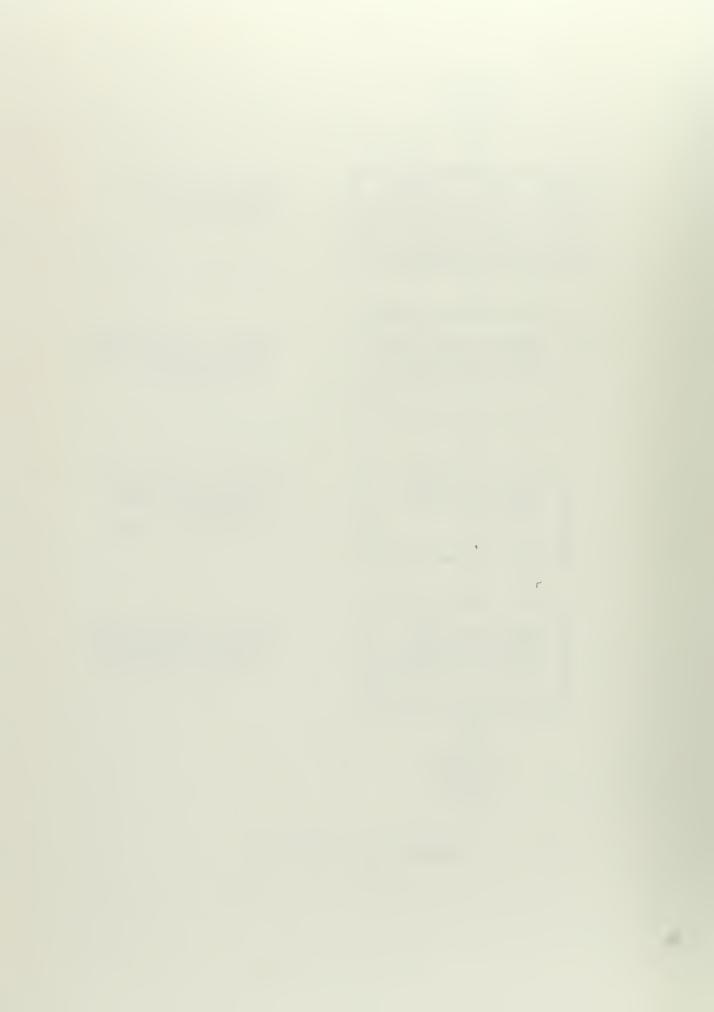


FIGURE III - Continued



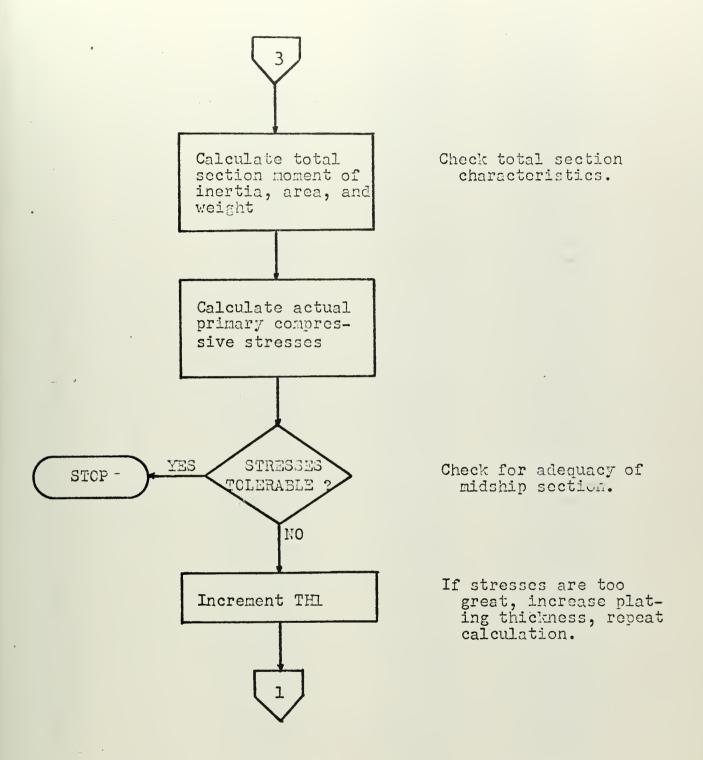


FIGURE III - Continued



| - 45 - | | | | |
|-------------------------------------------|-----|-------------------|----------------|------------------|
| I | J | PTDATA(I,J,1) | PTDATA(I, J, 2 | 2) PIDATA(1,J,3) |
| 1 | 1 | 0.0 | 0.0 | 0.200056 |
| 1 | 2 | 0.200000 | 0.004743 | 0.200057 |
| 1 | 3 | 0.400000 | 0.009515 | 0.200053 |
| 1 | 4 | 0.600000 | 0.014343 | 0.200060 |
| 1 | 5 | 0.800000 | 0.019255 | 0.200063 |
| 1 | 6 | 1.000000 | 0.024282 | 0.200067 |
| 1 | 7 | 1.200000 | 0.029449 | 0.200071 |
| 1 | 8 | 1.400000 | 0.034787 | 0.200075 |
| 1 | 9 | 1.599998 | 0.040322 | U.200083 |
| 1 | 10 | 1.799997 | 0.046084 | 0.200092 |
| 2 | 1 | 2.000000 | 0.052099 | 0.200099 |
| 2 | 2 | 2.200000 | 0.058402 | 0.200110 |
| 2 2 | 3 | 2.400000 | 0.065033 | 0.200121 |
| 2 | 4 | 2.599998 | 0.072038 | 0.200138 |
| 2 2 2 2 | 5 | 2.799997 | 0.079464 | 0.200155 |
| 2 | 6 | 2.999997 | 0.087355 | 0.200177 |
| 2 | 7 | 3.199999 | 0.095758 | 0.200200 ` |
| 2 | 8 | 3.399999 | 0.104718 | 0.200227 |
| 2 | 9 | 3.599998 | 0.114281 | 0.290260 |
| 2 | 10 | 3. 7 99995 | 0.124493 | 0.200300 |
| 3 | 1 | 4.000000 | 0.135401 | 0.400720 |
| 3 | 2 | 4.400000 | 0.159419 | 0.400908 |
| 3 | 3 | 4.799997 | 0.186407 | 0.401122 |
| 3 | 4 | 5.199999 | 0.216375 | 0.401354 |
| 3 | 5 | 5.599998 | 0.249332 | 0.401612 |
| 2 2 3 3 3 3 3 3 3 | 6 | 5.999996 | 0.285289 | 0.401894 |
| 3 | 7 | 6.399998 | 0.324254 | 0.402196 |
| 3 | 8 | 6.799995 | 0.366238 | 0.402525 |
| 3 | 9 | 7.199997 | 0.411250 | 0.402875 |
| 3 | 10 | 7.599997 | 0.459301 | 0.403255 |
| 4 | - 1 | 8.000000 | 0.510412 | 0.403664 |
| 4 | 2 | 8.400000 | 0.564682 | 0.404182 |
| 4 | 3 | 8.799997 | 0.622685 | 0.404840 |
| 4 | 4 | -9.199999 | 0.685097 | 0.405653 |
| 4 | 5 | 9.599998 | 0.752593 | 0.40652 |
| 4 | 6 | 9.999996 | 0.825849 | 0.407861 |
| 4 | 7 | 10.399998 | 0.905538 | 0.409308 |
| 4 | 8 | 10.799995 | 0.992337 | 0.411031 |
| 4 | 9 | 11.199997 | 1.086922 | 0.413059 |
| 4 | 10 | 11.599997 | 1.189965 | 0.415431 |
| 5 | 1 | 12.000000 | 1.302128 | 0.203281 |
| 5 5 5 | 2 | 12.194790 | 1.360265 | 0.203980 |
| 5 | 3 | 12.389580 | 1.420801 | 0.204727 |
| 5 | 4 | 12.584370 | 1.483809 | 0.205523 |
| 5 | 5 | 12.779160 | 1.549357 | 0.206371 |
| 5 | 6 | 12.973948 | 1.617520 | 0.207274 |
| 5 | 7 | 13.168737 | 1.688371 | 0.208232 |
| 5 | 8 | 13.363527 | 1.761974 | 0.209250 |
| 5 | 9 | 13.558317 | 1.838410 | 0.210327 |
| 5 | 10 | 13.753109 | 1.917747 | 0.210916 |
| 6 | 1 | 13.947900 | 1.998631 | 0.224085 |
| 6 | 2 | 14.153110 | 2.088647 | 0.225563 |
| 6 | 3 | 14.358317 | 2.182284 | 0.227193 |
| 6 | 4 | 14.563527 | 2.279781 | 0.229008 |
| 6 | 5 | 14.768739 | 2.381433 | 0.230972 |
| 6 | . 6 | 14.973948 | 2.487440 | 0.233151 |
| 6 | . 7 | 15.179156 | 2.598112 | 0.235502 |
| 6 | 8 | 15.384368 | 2.713654 | 0.238073 |
| 6 | 9 | 15.589578 | 2.834351 | 0.240840 |
| 6 | 10 | 15.794705 | 2.960419 | 0.250581 |
| 7 | 1 | 16.000000 | 3.104218 | 0.141439 |
| 7 | 2 | 16-117676 | 3.182663 | 0.142650 |
| 7 | 1 | 1/ 705/10 | 0 0/0017 | 0 1/2070 |



| - (| 4 | 16.353119 | 3.346128 | 0.145395 |
|----------|---------------|---------------------------------|------------------------|----------------------|
| 7 | 5 | 16.470810 - | 146 -3.431501 | 0.147028 |
| 7 | 6 | 16.588501 | 3.519608 | 0.149104 |
| 7 | 7 | 16.700238 | 3.611115 | 0.150991 |
| 7 | 8 | 16.823929 | 3.705704 | 0.153284 |
| 7 7 | 9 | 16.941620 | 3.803892 | 0.155638 |
| 8 | 10 | 17.059357 17.176529 | 3.905701 4.000000 | 0.150405 |
| 8 | 2 | 17.391129 | 4.200000 | 0.293348 |
| 8 | 3 | 17.597809 | 4.400000 | 0.282204 |
| 8 | 4 | 17.796921 | 4.599998 | 0.277075 |
| 8 | 5 | 17.988678 | 4.799997 | 0.272213 |
| 8 | 5 | 18.173340 | 4.999997 | 0.267623 |
| 8 | 7 | 18.351166 | 5.199999 | 0.263299 |
| 8 | 8 | 18.522400 | 5.399999 | 0.259253 |
| 8 | 9 | 18.687378 | 5.599998 | 0.255442 |
| 8 | 10 | 18.846283 | 5.799996 | 0.252185 |
| - 9 | 1 | 18.999878 | 6.000000 | 0.194464 |
| 9 | 2 3 | 19.115662 19.227997 | 6.156250 6.312500 | 0.192440 |
| 9 | 4 | 19.336884 | 6.468750 | 0.188472 |
| 9 | 5 | 19.442261 | 6.625000 | 0.186540 |
| 9 | 6 | 19.544159 | 6.781250 | 0.184647 |
| 9 | 7 | 19.642563 | 6.937500 | 0.182745 |
| 9 | 8 | 19.737320 | 7.093750 | 0.180912 |
| 9 | 9 | 19.828522 | 7.250000 | 0.179094 |
| 9 | 10 | 19.916031 | 7.406250 | 0.176460 |
| 10 | 1 | 19.998047 | 7.562500 | 0.049333 |
| 10 | 2 | 20.020844 | 7.606250 | 0.049214 |
| 10 | 3 | 20.043381 | 7.650000 | 0.049094 |
| 10 10 | 4 5 | 20.065659 20.087723 | 7.693748 7.737497 | 0.048999 |
| 10 | 6 | 20.109543 | 7.781247 | 0.048896 0.043836 |
| 10 | 7 | 20.131241 | 7.824999 | 0.048767 |
| 10 | 8 | 20.152802 | 7.868749 | 0.048693 |
| 10 | 9 | 20.174164 | 7.912498 | 0.048647 |
| 10 | 10 - | 20.195450 | 7.956246 | 0.049736 |
| 11 | 1 | 20.219101 | 8.000000 | 0.221883 |
| 11 | 2 | 20.315186 | 8.200000 | 0.221194 |
| 11 | 3 | 20.409668 | 8.400000 | 0.220430 |
| 11 | 4 | 20.502350 | 8.599998 | 0.219592 |
| 11 | 5 | 20.593018 | 8.799997 8.999997 | 0.218688 0.217743 |
| 11 11 | 6 7 | 20.681473 20.767563 | 9.199999 | 0.217745 |
| 11 | 8 | 20.850998 | 9.399999 | 0.215634 |
| 11 | 9 | 20.931595 | 9.599998 | 0.214540 |
| 11 | 10 | 21.009247 | 9.799996 | 0.213229 |
| 12 | 1 | 21.083176 | 10.000000 | 0.212228 |
| 12 | 2 | 21.154175 | 10.200000 | 0.211168 |
| 12 | 3 . | 21.221924 | 10.400000 | 0.210194 |
| 12 | 4 | 21.286606 | 10.599998 | .0.209312 |
| 12 | 5 | 21.348343 | 10.799997 | 0.208509 |
| 12 | 6 | 21.407303 | 10.999997 | 0.207792 |
| 12 | 7 | 21.463669 21.51 7 624 | 11.199999 11.399999 | 0.207150 0.206576 |
| 12 12 | 8 9 | 21.569336 | 11.599998 | 0.206064 |
| 12 | 10 | 21.618958 | 11.799996 | 0.205580 |
| 13 | 1 | 21.666504 | 12.000000 | 0.256441 |
| 13 | 2 | 21.723633 | 12.250000 | 0.255859 |
| 13 | 3 | 21.778061 | 12.500000 | 0.255320 |
| 13 | 4 | 21.829926 | 12.750000 | 0.254806 |
| 13 | 5 | 21.879181 | 13.000000 | 0.254342 |
| 13 | 6 | 21.925980 | 13.250000 | 0.253905 |
| 13 | 7 | 21.970337 | 13.500000 | 0.253502 |
| 13 | 8 | 22.012314 | 13.750000 | 0.253131 |
| 17 | 0 | / / // // // // | The Hall of the Late | 11 / 16 / (1) |



| 13 | 10 | 22.U37418 | 14.250000 | 0.252494 |
|----------|---------------|------------------------|------------------------|----------------------|
| 14 | 1 | 22.124878- | 47 - 14.500000 | 0.151348 |
| 14 | 2 | 22.145035 | 14.650000 | 0.151247 |
| 14 | 3 | 22.164429 | 14.799997 | 0.151147 |
| 14 | 4 | 22.183014 | 14.949999 | 0.151059 |
| 14 | 5 | 22.200382 | 15.099998 | 0.150970 |
| 14 | 6 | 22.217972 | 15.249996 | 0.150882 |
| 14 | 7 | 22.234253 | 15.399998 | 0.150799 |
| 14 | 8 | 22.249756 | 15.549995 | 0.150726 |
| 14 | 9 | 22.264542 | 15.699997 | 0.150649 |
| 14 | 10 | 22.278519 | 15.849997 | 0.150584 |
| 15 | 1 | 22.291733 | 16.000000 | 0.200665 |
| 15 | 2 | 22.308075 | 16.199997 | 0.200564 |
| 15 | 3 | 22.323166 | 16.399994 | 0.200475 |
| 15 | 4 | 22.337006 | 16.599991 | 0.200399 |
| 15 | 5 | 22.349686 | 16.799988 | 0.200334 |
| 15 15 | 6 7 | 22.361298 22.371933 | 16.999985 17.199982 | 0.200279 |
| 15 | 8 | 22.381699 | 17.199982 | 0.200235 0.200195 |
| 15 | 9 | 22.390610 | 17.599976 | 0.200195 |
| 15 | 10 | 22.398804 | 17.799973 | 0.200165 |
| 16 | 1 | 22.406235 | 18.000000 | 0.200118 |
| 16 | 2 | 22.413193 | 18.199997 | 0.200099 |
| 16 | 3 | 22.419571 | 18.399994 | 0.200080 |
| 16 | 4 | 22.425339 | 18.599991 | 0.200064 |
| 16 | 5 | 22.430527 | 18.799988 | 0.200049 |
| 16 | 6 | 22.435074 | 18.999985 | 0.200035 |
| 16 | 7 | 22.438965 | 19.199982 | 0.200023 |
| 16 | 8 | 22.442200 | 19.399979 | 0.200013 |
| 16 | 9 | 22.444748 | 19.599976 | 0.200006 |
| 16 | 10 | 22.446671 | 19.799973 | 0.200029 |
| 17 | 1 | 22.447342 | 20.000000 | 0.199998 |
| 17 | 2 | 22.447861 | 20.199997 | 0.199997 |
| 17 | 3 | 22.447678 | 20.399994 | 0.199999 |
| 17 | 4 | 22.446869 | 20.599991 | 0.200002 |
| 17 | 5 | 22.445450 | 20.799988 | 0.200006 |
| 17 | 6 | 22.443497 | 20.999985 | 0.200012 |
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| 18 | 2 | 22.422104 | 22.00000 | 0.200054 |
| 18 | 3 | 22.417328 | 22.399994 | 0.200060 |
| 18 | 4 | 22.412308 | 22.599991 | 0.200064 |
| 18 | 5 | 22.407120 | 22.799988 | 0.200068 |
| 18 | 6 | 22.401764 | 22.999985 | 0.200070 |
| 18 | 7 | 22.396378 | 23.199982 | 0.200073 |
| 18 | 8 | 22.390854 | 23.399979 | 0.200072 |
| 18 | 9 | 22.385376 | 23.599976 | 0.200071 |
| 18 | 10 | 22.379944 | 23 .7 99973 | 0.200092 |
| 19 | 1 | 22.374878 | 24.000000 | 0.123975 |
| 19 | 2 | 22.371613 | 24.123932 | 0.123989 |
| 19 | 3 | 22.368378 | 24.247864 | 0.123988 |
| 19 | 4 | 22.365189 | 24.371811 | 0.124003 |
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| 10 d 17 d 21 d 32 d 47 d 64 d 246 d 393 d | 27 27 27 27 27 27 27 27 27 28 28 28 28 28 28 29 29 29 29 29 29 29 29 29 29 30 30 30 30 30 30 30 30 30 30 30 30 30 |
|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (· I · · · · · · · · · · · · · · · · · | 23456789101234567891012345678910 |
| MIN. I. 1.404570 5.149980 1.267670 2.691560 3.848550 1.357809 12.129780 17.171539 91.923447 | 6.479360 6.255919. 6.032481 5.809045 5.585007 5.362166 5.138728 4.915292 4.691854 4.468413 4.244977 4.021539 3.798100 3.574660 3.351224 3.127786 2.904346 2.680907 2.457471 2.234033 2.010592 1.787154 1.563718 1.340280 1.116839 0.893403 0.669966 0.446528 0.223090 0.0 0.0 0.0 0.0 0.0 0.0 0.0 |
| AREA 2.547919 4.553559 2.935920 4.428200 4.322120 3.913119 8.529169 10.781560 20.686417 | 20.1301 26.1368 26.1498 26.1557 26.1619 26.1672 26.1772 26.1773 26.1828 26.1960 26.2008 26.2008 26.2008 26.2136 26.2136 26.2136 26.2234 26.2234 26.2252 26.2268 26.2281 26.2301 26.2301 26.2301 26.2311 26.2312 0.0 0.0 0.0 0.0 0.0 0.0 |
| VCG 4.102559 4.275189 5.179449 5.261410 6.916630 7.419299 10.944189 12.175449 16.908249 | 341 |
| DEPTH 6.000000 8.000000 8.000000 9.000000 12.000000 16.000000 18.000000 |)))))) |

112345678



```
50
                                     STZEST
    STICRK
                    STICRD
                                                      SGMULT
                                                                      SGMYLD
    7.929999
                    6.000000
                                     1.339286
                                                    20.982132
                                                                     20.982132
                         FRM
  W58MIN = 2.000000
                                   8.000000
  INTERIA THI = 0.343750 AND W5BACT = 2.162113
WSBACT
           2.162113
                      W5BPRC =
       =
                                  2.162113 W5BTOL =
                                                         0.0
       1
             J =
                         SUMDST =
                                    0.200056
  I =
                  1
  Ι
       1
             J =
                  2
                         SUMDST =
                                    0.400113
                         SUMDST =
       1
             J =
                  3
                                    0.600171
       1
             J
               =
                  4
                         SUMDST =
                                    0.800231
                  5
    =
       1
             J
               =
                         SUMDST =
                                    1.000294
              =
  I
       1
             J
                  6
                         SUMDST =
                                    1.200360
  Ι
                  7
       1
             J
                         SUMDST =
                                    1.400431
    =
       1
             J
               =
                  8
                         SUMDST =
                                    1.600505
  I-
       1
             J =
                  9
                         SUMDST =
                                    1.800588
   =
  I
       1
             J
               =
                 10
                         SUMDST =
                                    2.000679
       2
             J =
                         SUMDST =
                                    2.200778
      2.161354 Z = 0.057184
                                 YPR = 2.000000
                                                    ZPR = 0.052099
                    3.096774
 CLONGL OUTPUT =
                                    10.107035
                                                     2.161354
                                                                      0.057184
W5BACT =
          2.162113
                      W5BPRC =
                                 2.162113
                                              W5BTOL =
                                                         0.0
SPAN( 1)
          =
               2.162113
                           I =
                                 2
                                    J =
W5BACT
           2.162113
                       W5BPRC =
                                              W58TOL =
       =
                                 2.162113
                                                         2.166965
       2
  I =
             J =
                  2
                         SUMDST =
                                    0.238775
       2
                  3
  I
    =
             J =
                         SUMDST =
                                    0.438896
  I
       2
             J
              =
                         SUMDST =
                                    0.639034
    =
       2
  I
              =
                  5
                         SUMDST =
                                    0.839189
    =
             J
       2
  I
    =
             J
               =
                         SUMDST =
                                    1.039365
                  6
       2
                                    1.239564
                  ?
    =
             J
               ==
                         SUMDST =
  I
       2
             J
               =
                  8
                         SUMDST =
                                    1.439791
       2
    =
             J
               =
                  9
                         SUMDST =
                                    1.640050
       2
  I
              =
                         SUMDST =
                                    1.840349
    =
             J
                 10
       3
                                    2.241069
  I
                  1
                         SUMDST =
      4.326030
                                 YPR = 4.0000000
                                                    ZPR =
                 Z =
                       0.154977
                                                            0.135401
                                                     4.326030
CLONGL DUTPUT = 3.096774
                                   10.029918
                                                                    0.154977
W5BACT = 2.162113
                      W5BPRC =
                                 2.166965
                                              W5BTOL =
                                                         2.166965
SPAN( 2)
          =
               2.166965 I = 3 J = 1
W5BACT
                       W5BPRC = 2.166965
           2.162113
                                              W5BTOL =
                                                         2.175280
                                    0.475011
       3
                         SUMDST =
                  2
  [ =
             J =
  I
    =
       3
             J
               =
                  3
                         SUMDST =
                                    0.876133
  I
       3
                         SUMDST =
                                    1.277487
    =
             J
               =
                                    1.679098
  I
       3
               =
                  5
                         SUMDST
    =
                         SUMDST =
                                    2.080992
  I
    Ė
       3
             J
               =
                  6
       3
                   7
                         = TRGMUR
                                    2.483188
   =
               =
                                                    ZPR = 0.324254
 Y = 6.493771 Z =
                       0.334096
                                 YPR = 6.399998
                                     9.890423
 CLONGL OUTPUT = 3.096774
                                                     6.493771
                                                                      0.334096
W5BACT =
           2.162113
                       W5BPRC =
                                 2.175280
                                              W5BTOL = 2.175280
SPAN( 3)
               2.175280
                           I = 3
                                    J =
```



```
SUMDST =
                                 0.710433
       3
                 9
  I
                       SUMDST =
                                 1.113308
      3
            J =
                10
   =
                       SUMDST =
  I
   =
                 1
                       SUMDST =
                                 1.920226
      4
            J =
                 2
                       SUMDSI =
   =
                                 2.324408
    8.667541 Z · 0.503478 YPR = 8.400000 ZPR = 0.564682
CLONGL OUTPUT =
                  3.096174
                                 9.684793
                                                8.667541
                                                           0.603478
W5BACT = 2.162113 W5BPRC = 2.190565
                                         W5BTOL = 2.190565
SPAN(4) = 2.190505 I = 4 J = 2
W5BACT =
                     W5BPRC = 2.190565
          2.162113
                                          W5BTOL = 2.213699
  I =
            J =
                 3
                       SUMDST =
                                 0.538682
            J =
                       SUMDST =
                                 0.944335
  L
   =
       4
                 5
                       SUMDST =
                                 1.350987
   =
      4
            J =
                 6
                       SUMDST =
                                 1.758848
            J =
   =
      4
                 7
                       SUMDST =
                                 2.168156
                                 2.579186
                 8
                       SUMDST =
Y = 10.844317 Z = 1.002817 YPR = 10.799995
                                               ZPR = 0.992337
CLONGL DUTPUT = 3.096774
                                 9.388797
                                               10.844317
                                                               1.002317
W5BACT = 2.162113 W5BPRC = 2.213699 W5BTUL = 2.213699
SPAN( 5)
         = 2.213699 I = 4 J = 8
          2.162113
W5BACT =
                     W5BPRC = 2.213699
                                          W5BTOL = 2.248323
                       SUMDST =
 I =
      4
            J = 9
                                 0.778546
 I
   =
            J = 10
                       SUMDST =
                                 1.193976
  I
   =
       5
            J =
                       SUMDST =
                                 1.397257
                 1
       5
                       SUMDST =
                 2
                                 1.601236
       5
                 3
                                 1.805963
   =
            J =
                       SUMDST =
  I
       5
                 4
                       SUMDSI =
                                 2.011485
       5
                       SUMDST =
                                 2.217855
  I
   =
              =
                 5
       5
            J =
                       SUMDST =
                                 2.425129
   =
                 6
Y = 13.002581 Z =
                    1.627934 YPR = 12.973948
                                               ZPR = 1.617520
CLONGL OUTPUT = 3.096774
                                 8.945485
                                                13.002581
                                                                1.627934
W5BACT =
        2.162113
                     W5BPRC = 2.248323
                                          W5BTOL = 2.248323
SPAN( 6)
              2.248323 I = 5
                                 J = 6
W5BACT =
                     W5BPRC = 2.248323 W5BTOL = 2.303361
          2.162113
  = 1
       5
            J = 7
                       SUMDST =
                                 0.385037
  I =
       5
                                 0.594287.
            J =
                 8
                       SUMDST =
       5
                 9
                       SUMDST =
                                 0.804614
  I
              =
   =
       5
                                 1.015530
  I
               10
                       SUMDST =
            J
             =
  I
   =
       6
            J =
                 1
                       SUMDST =
                                 1.239614
  I
       6
              =
                 2
                       SUMDST =
                                 1.465177
                                 1.692369
  I
                 3
                       = TRGMUR
   =
              =
             =
                       SUMDST =
                                 1.921377
  I
   =
                 4
       6
  Ι
       6
              =
                 5
                       SUMDST =
                                 2.152349
                       SUMDST =
                                 2.385499
              =
                 6
Y = 15.106862 Z = 2.559123 YPR = 14.973948 ZPR = 2.487440
                                                                2.559123
 CLUNGL DUTPUT = 3.096774
                                 8.326877 15.106862
W5BACT = 2.162113
                     W50PRC =
                               2.303351
                                          W5BTOL = 2.303361
```



```
2.303361
SPAN( 7)
                                     J =
                                   2.303361
                       w53PRC =
W5BACT =
           2.162113
                                                W58TUL = 2.387387
                          SUMDST =
                                     0.317640
       6
             J =
  Ι
    =
        6
                   8
                          SUMDST =
                                     0.555713
             J
  I
    =
       6
               =
                   9
                          SUMDST =
                                     0.796553
  I
               = 10
                          SUMDST =
                                     1.047133
               =
        7
             J
  I
    =
                   1
                          SUMDST =
                                     1.188572
  Ι
        7
               =
                   2
                          SUMDST =
                                     1.331222
        7
  I
               =
                   3
                          SUMDST =
                                     1.475191
  I
        7
               =
    =
                   4
                          SUMDST =
                                     1.620585
        7
  I
               =
                   5
                          SUMDST =
                                     1.767613
  I
    =
        7
             J
               =
                          SUMDST =
                                     1.916717
                   6
        7
             J
               =
                   7
  Ι
                          SUMDST =
                                     2.067707
  Ι
        7
               =
                          SUMDST =
                                     2.220990
    =
                   8
                   9
  I
        7
               =
                          SUMDST =
    =
                                     2.376628
                 10
                          SUMDST =
                                     2.527033
Y = 17.067734
                Ζ =
                       3.912447
                                                              3.905701
                                  YPR = 17.059357
                                                      ZPR =
           2.162113
                        w58PRC =
W5BACT =
                                   2.387387
                                               W5BTOL =
                                                           2.387387
 CLONGL OUTPUT =
                     3.096774
                                      7.506919
                                                     17.067734
                                                                         3.912447
                       w53PRC =
W5BACT =
          2.162113
                                   2.387387
                                                45BTOL = 2.387387
SPAN( 8)
               2.387387 I = 7 J = 10
                                  2.387387
                       W5BPRC =
W5BACT =
           2.162113
                                                W5BTOL = 2.514391
  I =
                          SUMDST =
        8
                   1
                                     0.432994
  I
                   2
                                     0.720609
    =
        8
             J =
                          SUMDST =
  I
    =
        8
               =
                   3
                          SUMDST =
                                     1.002813
  I
        8
             J
                          SUMDST
  I
                   5
                                     1.552101
             J
                          SUMDST
    =
        ಶ
               =
               Ξ
                                     1.819724
  I
        8
                   6
                          SUMDST =
                   7
    =
        8
               =
                          SUMDST =
                                     2.083023
    =
        8
               =
                   8
                          SUMDST =
                                     2.342276
  I
              J
                   9
               =
                          = TRGMUR
                                     2.597717
 Y = 18.794434 Z =
                        5.734756
                                  YPR = 18.687378
                                                       ZPR =
                                                              5.599998
                                      6.528984
                                                      18.794434
                                                                         5.734756
 CLONGL DUTPUT = 3.096774
                        #5BPRC =
                                   2.514391
                                                W5BTOL = 2.514391
W5BACT =
           2.162113
                2.514391 I =
SPAN( 9)
                                  8 J =
W5BACT =
                        W5BPRC =
                                  2.514391
                                                W5BTOL = 2.696131
           2.162113
  I =
        8
             J = 10
                          SUMDST =
                                     0.335511
  I =
                                     0.529975
        9
              J =
                   1
                          SUMDST
                                  =
        9
                                     0.722415
  I
                   2
                          SUMDST
              J
                =
                                      0.912863
        9
                          SUMDST
  Ι
              J
                =
                   3
  I
    =
        9
              J
               =
                          SUMDST
                                      1.101335
                                      1.287874
        9
                =
                   5
                          SUMDST
  Ι
    =
              J
                                      1.472521
                          SUMDST =
        9
    =
              J
               =
                                      1.655266
        9
              J
               =
                   7
                          SUMDST =
  I
    =
                          SUMDST
  I
        9
              J
                =
                   8
                                      1.836177
  I
        9
                   9
                          SUMDST =
                                      2.015270
              J
                =
    =
                                      2.191730
                  10
                          SUMDST =
  ·I
        9
              J
                =
                                      2.241062
                          SUMDST =
    =
       10
              J
                =
                   1
                                      2.290276
       10
              J
                =
                   2
                          SUMDST =
       10
              J
                   3
                          SUMDST =
                                      2.339369
                                      2.383368
              J
               =
                          SUMDST
       10
                                      2.437263
               =
                   5
                          = T2GMUZ
    = 10
              J
                          SUMDST =
                                      2.486099
  I = 10
               =
                   6
              J
```



```
I = 10
                  8
                         SUMDST =
                                    2.583558
   = 10
                  9
  I
             J =
                         SUMDST =
                                    2.632205
             J = 10
    = 10
                         SUMDST =
                                    2.681940
             J =
  I = 11
                  1
                         SUMDST =
                                    2.903823
 Y = 20.225235 Z =
                     8.012792 YPR = 20.219101
                                                     ZPR = 8.000000
 CLONGL OUTPUT =
                    3.096774
                                     5.473187
                                                     20.225235
                                                                      3.012792
W5BACT =
          2.162113
                      W5BPRC =
                                  2.696131
                                              W5BTOL = 2.696131
SPAN(10)
               2.695131
                          I = 11
                                    J =
                                        1
                                  2.696131
W5BACT =
           2.162113
                       W5BPRC =
                                              W5BTOL =
                                                         2.944719
  I = 11
             J =
                  2
                         SUMDST =
                                    0.428886
                  3
  I = 11
             J =
                         SUMDST =
                                    0.649316
  I
    = 11
             J
              =
                  4
                         SUMDST =
                                    0.868908
                  5
  I = 11
               =
                         SUMDST =
             J
                                    1.087596
    = 11
             J
               =
                  6
                         SUMDST =
                                    1.305339
                  7
    = 11
             J =
                         SUMDST =
                                    1.522044
    = 11
             J =
                  8
                         SUMDST =
                                    1.737678
  I
    = 11
             J
               =
                  9
                         SUMDST =
                                    1.952217
  I
    = 11
             J
              =
                 10
                         SUMDST =
                                    2.165445
             J =
  I
   = 12
                  1
                         SUMDST =
                                    2.377673
                  2
                                    2.583840
  Ι
   = 12
             J
                         SUMDST =
                  3
  Ĺ
   = 12
             J
              =
                         SUMDST =
                                    2.799034
             J =
                  4
   = 12
                         SUMDST =
                                    3.008346
 Y = 21.329575
                 Z = 10.739202
                                 YPR = 21.286606
                                                    ZPR = 10.599998
 CLONGL OUTPUT =
                    3.096714
                                     4.402401
                                                     21.329575
                                                                     10.739202
W5BACT =
                                  2.944719
          2.162113
                       W5BPRC =
                                              W5BTOL =
                                                         2.944719
SPAN(11)
          =
               2.944719
                           I = 12
                                    J = 4
W5BACT =
                       W5BPRC = 2.944719
           2.162113
                                              W5BTOL =
                                                        3.283364
                         SUMDST =
                                    0.272135
  I = 12
             J =
                  5
                                    0.479927
  I = 12
             J =
                         SUMDST =
                  6
  I = 12
                  7
                         SUMDST
                                    0.687077
  I
                  8
   = 12
             J
               =
                         SUMDST =
                                    0.893653
  I
             J =
                  9
                                    1.099717
    = 12
                         SUMDST =
  I
    = 12
             J =
                 10
                         SUMDST =
                                    1.305297
  I
              =
                         SUMDST =
                                    1.561737
    = 13
             J
                  1
  I
    = 13
             J
               =
                  2
                         SUMDST =
                                    1.817595
   = 13
                  3
                         SUMDST =
                                    2.072915
  I
             J =
               =
                  4
                                    2.327721
  I
    = 13
             J
                         SUMDST =
                  5
                                    2.582062
  I
    = 13
             J =
                         SUMDST =
             J =
                                    2.835966
  I
   = 13
                  6
                         SUMDST =
  I = 13
             J =
                  7
                         SUMDST =
                                    3.089468
                                    3.342599
  I = 13
             J =
                  8
                         SUMDST =
                                                     ZPR = 13.750000
 Y = 22.042709 Z = 13.941499
                                 YPR = 22.012314
 CLONG! OUTPUT =
                    3.096174
                                     3.351851
                                                     22.042709
                                                                      13.941499
W5BACT =
                       W5BPRC =
                                  3.283364
                                              W5BTOL =
                                                        3.283364
           2.162113
SPAN(12)
                           I = 13
                                    J = 8
           =
               3.283354
W5BACT =
                       W5BPRC = 3.283364
                                              W5BTOL =
                                                        3.762891
           2.162113
  I = 13
                         SUMDST =
                                    0.312026
             J =
                                    0.564520
  I = 13
             J = 10
                         SUMDST =
                                    0.715868
  I = 14
             J =
                   1
                         SUMDST =
                   2
                         SUMPST =
                                    0.867115
  I
    = 14
```



```
1.169319
            J =
  I
   = 14
                  5
                        SUMDST =
                                   1.320289
   = 14
            J
              =
                  6
                        = IZGHUZ
                                   1.471170
   = 14
            J =
                 7
                        SUADSI =
                                   1.621969
  I
   = 14
            J
              = 8
                        SUMDST =
                                   1.772695
   = 14
              =
                 9
            J
                        SUMDST =
                                   1.923343
  I
   = 14
            J
              = 10
                        SUMDST =
                                   2.073926
   = 15
            J
              =
                 -1
                        SUMDST =
                                   2.274590
   = 15
              =
  I
            J
                  2
                        SUMDST =
                                   2.475154
  I
   = 15
            J
              =
                 3
                        SUMDST =
                                   2.675629
  I
   = 15
            J
              =
                 4
                        SUMDST =
                                   2.876027
  I
   = 15
            J
              Ξ
                 5
                        SUMDST =
                                   3.076361
            J =
  I
   = 15
                  6
                        SUMDST =
                                   3.276639
  I
   = 15
            J
              =
                 7
                        SUMDST =
                                   3.476873
  Ι
   = 15
            J
              =
                 8
                        SUMDST =
                                   3.677068
            J =
  I
   = 15
                 9
                        SUMDST =
                                   3.877233
Y = 22.394119 Z = 17.685715 YPR = 22.390610
                                                  ZPR = 17.599976
CLONGL OUTPUT = 3.096774
                                    2.714253
                                                  22.394119
                                                                   17.685715
W5BACT = 2.162113 W5BPRC = 3.762891
                                            W5BTOL = 3.762891
SPAN(13)
         = 3.762891 I = 15
                                   J = 9
W5BACT =
          2.162113
                      W5BPRC = 3.762891
                                            W5BTOL = 4.181564
  I = 15
            J = 10
                        SUMDST =
                                   0.314507
            J =
  I = 16
                  1
                        SUMDST =
                                   0.514625
  I = 16
              =
                  2
                        SUMDST =
                                   0.714724
            J
                  3
  I = 16
              =
                        SUMDST =
                                   0.914804
            J
            J =
  I
   = 16
                 4
                        SUMDST =
                                   1.114867
            J =
                 5
  I
                        SUMUST =
   = 16
                                   1.314916
  I
   = 16
            J
              =
                  6
                        SUMDST =
                                   1.514950
              = 7
  I
   = 16
            J
                        SUMDST =
                                   1.714972
   = 16
              =
                                   1.014585
  I
            J
                  8
                        SUMDST =
  Ι
   = 16
            J
              =
                9
                                   2.114490
                        SUMDST =
  I
   = 16
            J
              = 10
                       · SUMDST =
                                   2.315019
  I
   = 17
              =
                                   2.515017
            J
                 1
                        SUMDST =
  I
              =
   = 17
            J
                  2
                        SUMDST =
                                   2.715014
  I
   = 17
              = 3
                                   2.915012
            J
                        SUMDST =
  I
   = 17
            J
              =
                 4
                        = TROMUZ
                                   3.115014
  I
   = 17
            J
              =
                 5
                        SUMDST =
                                   3.315020
  I = 17
            J
              =
                  6
                        SUMDST =
                                   3.515031
            J
              =
  I
   = 17
                 7
                        SUMDST =
                                   3.715050
  I
              =
   = 17
            J
                 8
                        SUMDST =
                                   3.915074
  I
   = 17
              =
                  9
                        SUMDST =
                                   4.115107
  I
   = 17
            J = 10
                        SUMDST =
                                   4.315178
Y = 22.429413 Z = 21.866409 YPR = 22.430832
                                                   ZPR = 21.799973
                    W5BPRC = 4.181564 W5BTOL = 4.181564
W5BACT = 2.162113
CLONGL OUTPUT =
                    3.096774
                                   2.061488
                                                  22.429413
                                                                   21.865409
                      W58PRC = 4.181564
                                            W5BTOL = 4.181564
W5BACT =
          2.162113
SPAN(14)
          = 4.181564 I = 17 J = 10
W5BACT =
                      W5BPRC =
                               4.181564
                                            W5BTUL = 3.582258
          2.162113
  I = 18
                        SUMDST =
                                   0.333661
            J =
                 - 1
                      SUMDST =
  I = 18
                  2
                                   0.533715
            J
              =
  I = 18
              =
                  3
                        SUMDST =
                                   0.733774
  I = 18
            J =
                        SUMDST =
                                   0.933838
                  4
  I
   = 18
             J
              =
                  5
                        SUMDST =
                                   1.133906
  I = 18
                  6
                        SUMDST =
                                   1.333976
            .) =
```

= 14

=

29WD21 =



```
=
      18
                          SUMDST
                                      1.734119
  I
    =
      18
                =
                   9
                          SUMDS: =
                                      1.934190
      ^{-18}
                  10
                =
                          SUMDST =
                                      2.134281
      19
              J
                =
                          SUMDST =
                   1
                                      2.258256
    =
      19
                =
                   2
                          SUMDST =
                                      2.382244
  I
    =
      19
              J
                =
                   3
                          SUMDST =
                                      2.506231
      19
              J
                =
                   <u>/</u>;
                          = TRGMUZ
                                      2.630234
                   5
    = 19 .
              J
                =
                          TRUMUS
                                      2.754219
    =
      19
              J
                =
                   6
                          SUMDST =
                                      2.878203
    = 19
              J
                =
                   7
                          SUMDST
                                      3.002172
    = 19
                =
  I
              J
                   8
                          SUMDST =
                                      3.126157
                =
  I
    = 19
                   9
              J
                          SUMDST =
                                      3.250141
    = 19
                = 10
                          SUMDST =
                                      3.374258
SPAN(15)
          =
                3.374258
                            I = 19
                                      J = 10
 Y = 22.343796
                  Z = 25.239594
                                  YPR = 22.343796
                                                      ZPR = 25.239594
  I = 20
                          SUMDST =
                   1
                                      0.224005
                   2
                                      0.447998
  I
    = 20
              J =
                          SUMDST =
    = 20
                   3
              J
                =
                          SUMDST =
                                      0.671974
    = 20
                =
              J
                   4
                          SUMDST =
                                      0.895963
    =
      20
                =
                   5
                          SUMDST =
              J
                                      1.119967
    = .20
                =
              J
                   6
                          SUMDST =
                                      1.343939
  I
    = 20
              J
                =
                   7
                          TROMUZ
                                      1.567926
                                  =
                =
    = 20
                   8
                          SUMDST
                                      1.791924
  I
    = 20
              J
                =
                   9
                          SUMDST =
                                      2.015907
  I
    =
     20
                =
                  10
              J
                          SUMDST
                                      2.239871
  I
     21
    =
              J
                =
                   1
                          SUMDST
                                  =
                                      2.463848
    = 21
                =
                   2
                          SUMDST =
              J
                                      2.681837
  I
      21
              J
                =
                   3
                          SUMDST =
                                      2.911792
  I
      21
                =
    =
              J
                   4
                          SUMDST =
                                      3.135758
  I
                =
                   5
    =
      21
                          SUMDST =
                                      3.359739
                                      3.583699
  I
      21
                          SUMDST =
    =
                =
 Y = 18.769989
                 Z = 25.486084
                                  YPR = 18.992035
                                                       ZPR = 25.471035
 CLONGL OUTPUT =
                     3.096774
                                       1.329552
                                                       18.769989
                                                                         25.486084
W5BACT =
           2.162113
                        W5BPRC =
                                    3.582268
                                                W5BTUL = 3.582268
SPAN(16)
                3.582268
                            I = 21
           2.162113
                                  3.582268
W5BACT =
                        W5BPRC =
                                                W58TOL =
                                                            3.019865
  I = 21
                          SUMDST =
                                      0.225371
              J =
              J =
  I = 21
                   8
                          TROMUZ
                                  =
                                      0.449340
    = 21
                =
                   9
                          SUMDST
                                      0.673287
              J
    = 21
                                      0.897214
                  10
                          SUMDST
                =
                                      1.121151
  Ι
    =
      22
                =
                          SUMDST
              J
                   1
    = 22
              J
                =
                   2
                          SUMDST
                                      1.345098
  Ι
    = 22
                          SUMDST
                                      1.569009
                =
                   3
  I
                          SUMDST
                                      1.792931
      22
              J
                =
                   4
                                  =
    = 22
                   5
                          SUMDST
                                      2.016862
              J
                =
  I
    = 22
              J
                =
                   6
                          SUMDST
                                      2.240771
  I
    = 22
                =
                   7
                          SUMDST
                                      2.464658
              J
                                      2.688555
  Ι
    = 22
                =
                   8
                          SUMDST =
                                      2.912435
                   9
  I
    = 22
                =
                          SUMDST
                                  =
    = 22
                = 10
                          SUMDST =
                                      3.136307
 Y = 15.756542
                  Z = 25.682541
                                   YPR = 15.863767
                                                       ZPR = 25.675858
                       W5BPRC =
                                    3.019865
                                                W5BTOL = 3.019865
W5BACT = 2.162113
 CLONGL DUTPUT =
                     3.096774
                                       1.284049
                                                      15.756542
                                                                         25.682541
                                                W58TOL =
W5BACT =
           2.162112
                        W53PRC =
                                    3.019865
                                                            3.019865
```



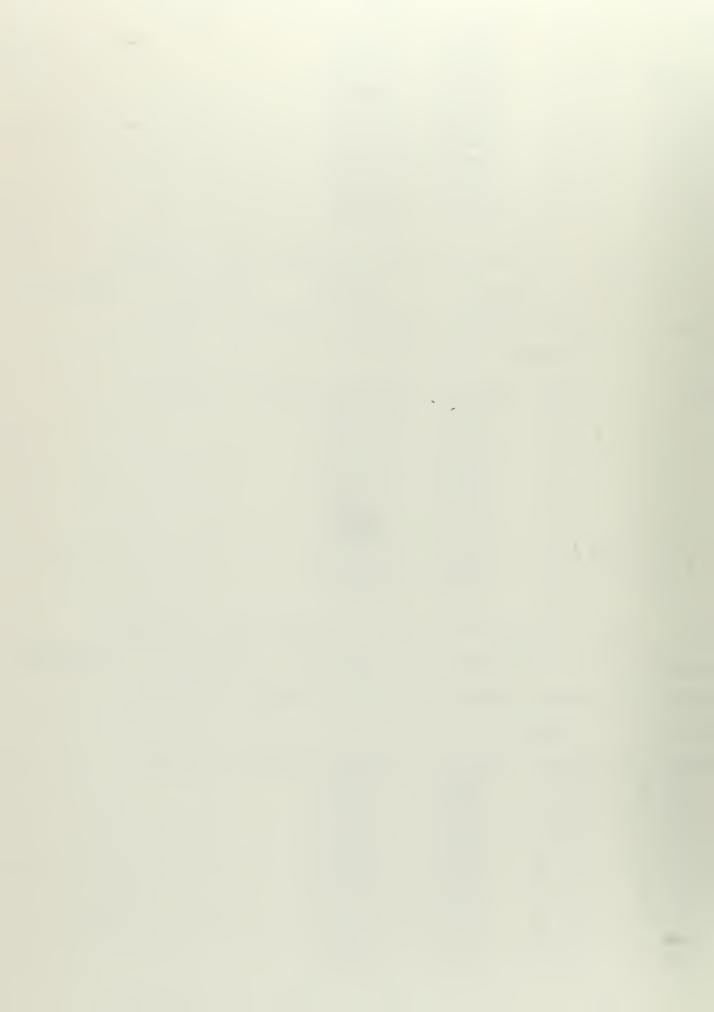
```
- 56 -
W5BACT =
           2.152113
                        W5BPRC =
                                    3.019865
                                                W5BTUL =
                                                           2.952949
  I = 23
              J =
                    1
                           = TROMUR
                                      0.340307
    = 23
              J
               =
                   2
  I
                           SUMDST =
                                      0.504165
      23
    =
              J
               =
                   3
                           SUMDST =
                                      0.788016
    =
      23
              J
                =
  I
                   4
                           SUMDST =
                                      1.011861
       23
                   5
    =
              J
                =
                           SUMDST
                                      1.2354.97
    =
       23
              J
                =
                   5
                          SUMDST =
                                      1.459523
      23
              J
               =
                   7
  I
                           SUMDST
                                      1.683344
      23
               =
  I
    =
              J
                   8
                           SUMDST
                                      1.907159
                =
                   9
  I
    =
      23
              J
                           SUMDST
                                      2.130963
  Ι
    = 23
              J
               =
                  10
                           SUMDST
                                      2.354760
  I
    =
      24
              J
               =
                           SUMDST
                                      2.578547
                   1
                                  =
  Ι
    =
      24
              J
                   2
                           SUMDST =
                                      2.802330
    = 24
              J
               =
                   3
                           SUMDST =
                                      3.026100
 Y = 12.798687 Z = 25.856140
                                   YPR = 12.959067
                                                        ZPR = 25.847382
 CLONGL OUTPUT =
                      3.096774
                                       1.243269
                                                        12.798687
                                                                         25.856140
W5BACT =
           2.162113
                        W5BPRC =
                                    2.962949
                                                 W5BTOL = 
                                                            2.962949
SPAN(18)
                2.962949
                             I = 24
                                      J =
                                    2.962949
W5BACT =
                        W5BPRC =
           2.162113
                                                 w5BTOL =
                                                            2.939541
  I = 24
                           SUMDST
              J =
                   4
                                  =
                                      0.286916
                   5
    = 24
              J
               =
                           SUMDST =
                                      0.510673
  I
    = 24
              J
               =
                   6
                           SUMDST
                                      0.734420
      24
              J
               =
                   7
                           SUMDST
                                      0.958159
  I
  I
      24
              J
                   8
                           SUMDST
                                      1.181889
    =
               =
                   9
  I
      24
              J
               =
                           TROMUR
                                      1.405612
    =
                                  =
    =
       24
              J
                =
                  10
                           SUMDST =
                                      1.629326
  I
                           SUMDST =
                                      1.853028
      25
              J
                =
    =
                   1
  I
    =
      25
              J
               =
                   2
                           SUMDST =
                                      2.070:24
  I
    =
       25
              J
               =
                   3
                           SUMDST
                                      2.300413
  I
      25
              J =
                   4
                          SUMDST
                                  =
                                      2.524093
    =
  I
    = 25
              J =
                   5
                           SUMDST =
                                      2.747762
                                      2.971424
    = 25
               =
                           SUMDST =
 Y =
       9.862784
                  Z = 26.002213
                                   YPR = 10.054372
                                                        ZPR = 25.993622
 CLONGL OUTPUT =
                      3.096774
                                       1.208532
                                                         9.862784
                                                                         26.002213
                        W5BPRC =
W5BACT =
           2.162113
                                    2.939541
                                                 W5BTOL =
                                                            2.939541
SPAN(19)
                2.939541
                          I = 25
                                      J =
                                            6
                                    2.939541
W5BACT =
                        W5BPRC =
                                                 w5BTOL =
                                                            2.921926
           2.162113
  I = 25
                           SUMDST =
                                      0.255539
              J
                                      0.479186
    =
       25
                =
                    8
                           SUMDST =
  I
      25
                   9
                           SUMDST
                                   =
                                      0.702823
    =
              J
                =
  I
    = 25
              J
               =
                  10
                           SUMDST
                                      0.926453
                                      1.150075
    =
       26
              J
                =
                    1
                           SUMDST
                                      1.373689
                   2
                           SUMDST
                                  =
       26
    =
              J
                =
                   3
                                      1.597293
  I
    =
      26
              J
                =
                           SUMDST
                                      1.820891
    =
       26
              J
                =
                   4
                           SUMDST
                                  =
                    5
                                      2.044482
               =
                           SUMDST
                                  =
    =
       26
              J
                           SUMDST
                                      2.268063
  I
    =
       26
              J =
                   6
                   7
                                      2.491637
  I
    =
       26
              J
                =
                           SUMDST
                                      2.715206
  I
    =
       26
              J
                =
                    8
                           SUMDST
                                  =
                                      2.938766
      26
               =
                   9
                           SUMDST =
 Y =
       6.943064
                  Z = 26.115402
                                  YPR =
                                            7.149673
                                                        ZPR = 26.108582
```

SPAN(17)

3.019365

I = 22

J = 10



```
W5BACT = 2.162113
                     W58PRC =
                                2.921926
                                           W5BTOL =
                                                     2.921926
             2.921926 I = 26 J = 9
SPAN(20)
                     W5BPRC = 2.921926
W5BACT =
          2.162113
                                          W5BTOL = 2.908485
 I = 26
           J = 10
                       SUMDST = 0.240392
  I = 27
            J =
                 -1
                       SUMDST =
                                  0.463939
  I = 27
                 2
             =
                       SUMDST =
            J
                                  0.65/479
  I = 27
              =
                 3
                                  0.911013
            J
                       SUMDST =
  I = 27
             =
                 4
            J
                       SUMDST =
                                  1.134539
  I = 27
                 5
            J =
                       SUMDST =
                                  1.358059
            J =
  I = 27
                 6
                       SUMDST =
                                  1.581574
  I = 27
                 7
            J =
                       SUMDST =
                                  1.805083
  I = 27
            J =
                 8
                       SUMDST =
                                  2.028584
  I = 27
                 9
                       SUMDST =
            J =
                                  2.252082
   = 27
            J =
                10
                       SUMDST =
                                  2.475574
  I = 28
            J =
                1
                       SUMDST =
                                  2.699061
                 2
  I = 28
            J =
                       SUMDST =
                                  2.922544
Y = 4.035593 Z = 26.191559 YPR = 4.244977 ZPR = 26.187378
CLONGL OUTPUT = 3.096774
                                  1.162918
                                                  4.035593
                                                           26.191559
W5BACT = 2.162113 W5BPRC = 2.908485 W5BTOL = 2.908485
          = 2.908485 I = 28 J = 2
SPAN(21)
W5BACT =
          2.162113
                     W5BPRC = 2.908485
                                          W58TOL = 2.899400
 I = 28
                3
                       SUMDST = 0.237537
            J =
            J =
  I = 28
                 4
                        SUMDST =
                                  0.461010
            J =
                 5
  I = 28
                       SUMDST =
                                  0.684479
  I = 28
                                  0.907945
            J
             =
                 6
                       SUMDST =
            J =
                       SUMDST =
  I = 28
                 7
                                  1.131408
                                  1.354366
  I = 28
            J =
                 8
                       SUMDST =
                 9
  I = 28
                                  1.578321
            J =
                       SUMDST =
  I = 28
            J = 10
                      SUMDST =
                                 1.801773
                       SUMDST =
  I = 29
            J =
                                  2.025224
                 1
  I = 29
                 2
                                  2.248672
            J =
                        SUMDST =
  I = 29
            J =
                 3
                        SUMDST =
                                  2.472116
                        SUMDST =
  I = 29
            J =
                 4
                                  2.695560
                 5
  I = 29
                       SUMDST =
                                  2.919003
Y = 1.136441 Z = 26.228058 YPR = 1.340280
                                                ZPR = 26.226822
                                   1.154048
                                                  1.136441
CLONGL OUTPUT = 3.096774
                                                                 26.228058
W5BACT = 2.162113
                    W5BPRC = 2.899400
                                           W5BTOL = 2.899400
SPAN(22)
          =
              2.899400 I = 29 J = 5
                     W5BPRC = 2.899400
                                           W5BTOL = 2.894860
W5BACT =
          2.162113
                        SUMDST = 0.243043
  I = 29
            J =
                 6
  I = 29
            J =
                 7
                        SUMDST =
                                  0.466482
                                  0.689921
  I = 29
            J =
                 8
                        SUMDST =
                        SUMDST =
  I = 29
            J =
                 9
                                  0.913359
            J = 10
  I = 29
                        SUMDST =
                                 1.136448
                                 1.136448
                       SUMDST =
  I = 30
            J =
                - 1
```

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```
58 YPR
                             Z
                                                               ZPR
                                                                              SPAN(I)
I
                            0.154977
 2
          4.326030
                                             4.000000
                                                               0.135401
                                                                                2.166965
 3
          6.493771
                           0.334096
                                             6.399998
                                                               0.324254
                                                                                2.175280
          8.667541
 4
                           0.603478
                                             8.400000
                                                               0.554582
                                                                                2.190565
 5
         10.844317
                            1.002817
                                            10.799995
                                                               0.992337
                                                                                2.213699
 6
         13.002581
                            1.627934
                                            12.973948
                                                               1.617520
                                                                                2.248325
 7
         15.106862
                            2.559123
                                                               2.487440
                                                                                2.303361
                                            14.973948
 8
         17.067734
                            3.912447
                                            17.059357
                                                               3.905701
                                                                                2.387387
9
         18.794434
                            5.734756
                                                               5.599998
                                                                                2.514391
                                            18.687378
         20.225235
                            8.012792
                                            20.219101
                                                                                2.696131
10
                                                               8.000000
         21.329575
                           10.739202
                                            21.286606
                                                              10.599998
                                                                                2.944719
11
12
         22.042709
                           13.941499
                                            22.012314
                                                              13.750000
                                                                                3.283364
         22.394119
                          17.685715
                                                                                3.762891
13
                                            22.390610
                                                              17.599976
         22.429413
14
                          21.866409
                                            22.430832
                                                              21.799973
                                                                                4.131564
15
         22.343796
                          25.239594
                                            22.343796
                                                              25.239594
                                                                                3.374258
                                                                                3.582268
         18.769989
                           25.486084
                                            13.992035
                                                              25.471085
16
17
         15.756542
                           25.682541
                                            15.863767
                                                              25.675858
                                                                                3.019865
                           25.856140
                                                                                2.962949
         12.798587
                                            12.959067
                                                              25.847382
18
19
          9.862784
                          26.002213
                                            10.054372
                                                              25.943622
                                                                                2.939541
20
          6.943064
                           26.115402
                                             7.149673
                                                              26.108582
                                                                                2.921926
          4.035593
                           26.191559
                                             4.244977
                                                              26.187378
                                                                                2.908485
21
22
          1.136441
                           26.228058
                                             1.340280
                                                              26.226822
                                                                                2.899400
                                                                                1.135448
23
          0.0
                            0.0
                                             0.0
                                                               0.0
                                                                                0.0
24
          0.0
                            0.0
                                             0.0
                                                               0.0
                                                                                0.0
25
          0.0
                            0.0
                                             0.0
                                                               0.0
                                                                                0.0
                            0.0
                                             0.0
                                                               0.0
26
          0.0
                                                                                0.0
27
                            0.0
                                             0.0
                                                               0.0
          0.0
                            0.0
                                             0.0
                                                               0.0
                                                                                0.0
28
          0.0
                                                                                0.0
                                             0.0
                                                               0.0
29
          0.0
                            0.0
                                             0.0
                                                                                0.0
                            0.0
                                                               0.0
30
          0.0
                            0.0
                                             0.0
                                                               0.0
                                                                                0..0
31
          0.0
                                             0.0
                                                               0.0
                                                                                0.0
32
          0.0
                            0.0
                            0.0
                                             0.0
                                                               0.0
                                                                                0.0
33
          0.0
                            0.0
                                             0.0
                                                               0.0
                                                                                0.0
34
          0.0
                                             0.0
                                                               0.0
                                                                                 0.0
35
          0.0
                            0.0
                                                                                0.0
                            0.0
                                             0.0
                                                               0.0
36
          0.0
                                                               0.0
                                                                                0.0
                            0.0
                                             0.0
37
          0.0
                                                               0.0
                                                                                0.0
                                              0.0
                            0.0
38
          0.0
                                                               0.0
                                                                                0.0
                            0.0
                                              0.0
39
          0.0
                                                               0.0
                                                                                 0.0
40
          0.0
                            0.0
                                             0.0
```

```
CGCG(1) = 1.459806
```

LONGITUDINAL (1) IS SELECTED

CGCG(1) = 2.107491

LONGITUDINAL (2) IS SELECTED

CGCG(1) = 1.948315

LONGITUDINAL (3) IS SELECTED

CGCG(1) = 2.499537

LONGITUDINAL (4) IS SELECTED

CGCG(1) = 3.166034

LUNGITUDINAL (5) IS SELECTED

CGCG(2) = 3.166634



```
CGCG(3) = 3.166634 - 59 -
```

LONGITUDINAL (5) IS SELECTED

CGCG(4) = 3.166634

LUNGITUDINAL (5) IS SELECTED

CGCG(5) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(6) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(7) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(8) = 3.166634

LUNGITUDINAL (5) IS SELECTED

CGCG(9) = 3.165634

LONGITUDINAL (. 5) IS SELECTED

CGCG(10) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(111) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(12) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(13) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(14) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(15) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(16) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(17) = 3.166634

LONGITUDINAL (5) IS SELECTED

CGCG(18) = 3.166634

LONGITUDINAL (5) IS SELECTED



```
LUNGITUDINAL ( 5) IS SELECTED - 60 -
CGCG(20) = 3.166634
LONGITUDINAL ( 5) IS SELECTED
CGCG(21) = 3.166634
LONGITUDINAL ( 5) IS SELECTED
CGCG(22) = 3.166634
LONGITUDINAL ( 5) IS SELECTED
I = 1 HM = 30.174057
LONGITUDINAL ( 5) IS SELECTED
I = 2 HM = 30.076263
LONGITUDINAL ( 5) IS SELECTED
I = 3 HM = 29.897141
LONGITUDINAL ( 5) IS SELECTED
I = 4 HM = 29.627762
LONGITUDINAL ( 5) IS SELECTED
I = 5 HM = 29.228424
LONGITUDINAL ( 5) IS SELECTED
I = 6 + HM = 28.603302
LONGITUDINAL ( 5) IS SELECTED
I = 7 HM = 27.672119
LONGITUDINAL ( 5) IS SELECTED
I = 8 \quad HM = 26.318787
LONGITUDINAL ( 5) IS SELECTED
I = 9 HM = 24.496490
LONGITUDINAL ( 5) IS SELECTED
I = 10 HM = 22.218445
LONGITUDINAL ( 5) IS SELECTED
I = 11 HM = 19.492035
LONGITUDINAL ( 5) IS SELECTED
I = 12 HM = 16.289734
LONGITUDINAL ( 5) IS SELECTED
I = 13 HM = 12.545532
```



```
I = 14 HM = 8.364838
LONGITUDINAL ( 5) IS SELECTED
I = 15 HM = 4.991653
LONGITUDINAL ( 5) IS SELECTED
I = 16 \cdot HM = 4.745163
LONGITUDINAL ( 5) IS SELECTED
I = 17 HM = 4.548706
LUNGITUDINAL ( 5) IS SELECTED
I = .18 HM = 4.375107
LONGITUDINAL ( 5) IS SELECTED
I = 19 HM = 4.229034
LONGITUDINAL ( 5) IS SELECTED
I = 20 HM = 4.115845
LONGITUDINAL ( 5) IS SELECTED
I = 21 HM = 4.039638
LONGITUDINAL ( 5) IS SELECTED
I = 22 HM = 4.003189
LONGITUDINAL ( 5) IS SELECTED
XMINER(1) = 160.853806
XMINER( 2) = 160.853806
XMINER(3) = 160.853806
XMINER(4) = 160.853806
XMINER(5) = 160.853806
XMINER(6) =
             160.853806
XMINER( 7) = 160.853806
XMINER(8) = 160.853806
             160.853306
XMINER(9) =
XMINER(10) = 160.853806
XMINER(11) = 160.853806
XMINER(12) = . 160.853806
XMINER(13) = 160.853806
XMINER(14) = 160.853806
```

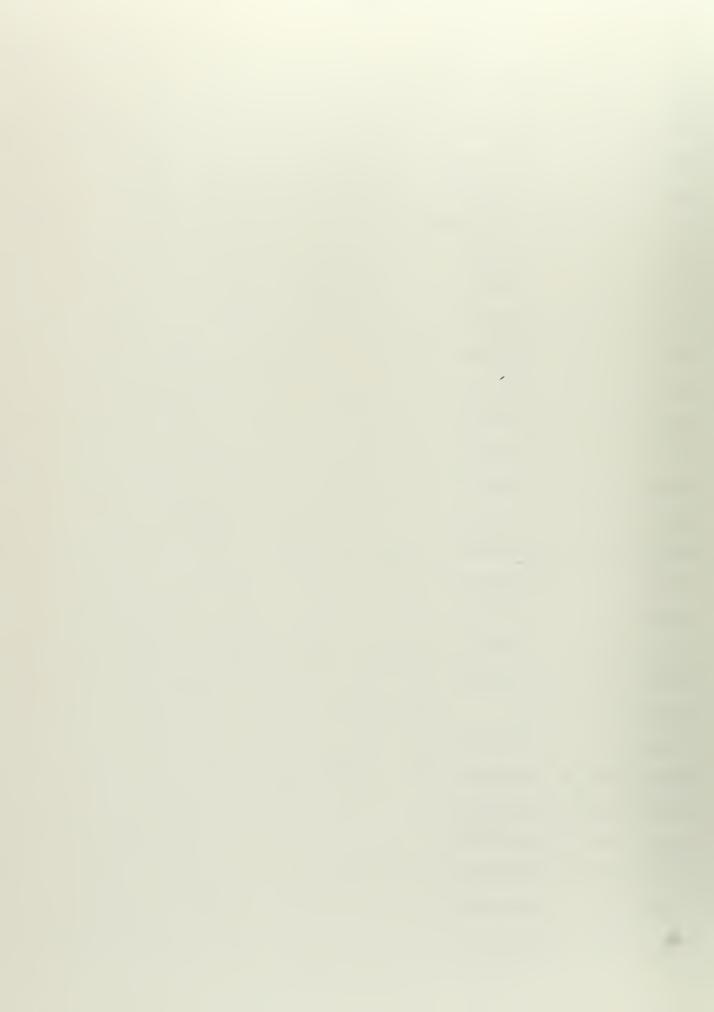
- 61 -



| XMINEX(16) = | 160.853806 |
|--------------|----------------|
| XMINER(17) = | 160.853806 |
| XMINER(18) = | 160.853306 |
| XMINER(19) = | 160.353806 |
| XMINER(20) = | 160.853806 |
| xMINER(21) = | 160.853806 |
| XMINER(22) = | 160.853806 |
| LONGITUDINAL | 5) IS SELECTED |
| BASEMT(1) = | 1.465505 |
| BASEMT(2) = | 0.730327 |
| BASEMT(3) = | 0.907333 |
| BASEMT(4) = | 1.173897 |
| BASEMT(5) = | 1.563735 |
| BASEMT(6) = | 2.169605 |
| BASEMT(7) = | 3.066433 |
| BASEMT(8) = | 4.361360 |
| BASEMT(9) = | 6.093286 |
| BASEMT(1C) = | 8.262015 |
| BASEMT(11) = | 10.909203 |
| BASEMT(12) = | 14.031854 |
| BASEMT(13) = | 17.709274 |
| BASEMT(14) = | 21.854095 |
| BASEMT(15) = | 0.0 |
| BASEMT(16) = | 24.910995 |
| BASEMT(17) = | 25.107269 |
| BASEMT(18) = | 25.280609 |
| BASEMT(19) = | 25.426392 |
| BASEMT(20) = | 25.539322 |
| BASEMT(21) = | 25.615280 |

BASEMT(22) = 25.651672

- 62 -



| SPAN(1) | = | 2.162113 |
|----------|---|----------|
| SPAN(2) | = | 2.106965 |
| SPAN(3) | Ξ | 2.175280 |
| SPAN(4) | = | 2.190505 |
| SPAN(5) | = | 2.213699 |
| SPAN(b) | = | 2.248323 |
| SPAN(7) | = | 2.303361 |
| SPAN(8) | = | 2.387387 |
| SPAN(9) | = | 2.514391 |
| SPAN(10) | = | 2.696131 |
| SPAN(11) | = | 2.944719 |
| SPAN(12) | = | 3.283364 |
| SPAN(13) | = | 3.762891 |
| SPAN(14) | = | 4.181564 |
| SPAN(15) | = | 3.374258 |
| SPAN(16) | = | 3.582268 |
| SPAN(17) | = | 3.019865 |
| SPAN(18) | = | 2.902949 |
| SPAN(19) | = | 2.939541 |
| SPAN(20) | = | 2.921926 |
| SPAN(21) | = | 2.908485 |
| SPAN(22) | = | 2.899400 |
| SPAN(23) | = | 1.136448 |
| SPAN(24) | = | 0.0 |

SPAN(25)

SPAN(26)

SPAN (27)

SPAN(28)

SPAN(29)

SPAN(30)

SPAN(31)

SPAN(32)

0.0

0.0

0.0

0.0

0.0

0.0

0.0

0.0



SPAN(33) = 0.0SPAN(34) = 0.0

SPAN(35) = 0.0

SPAN(36) = 0.0

SPAN(37) = 0.0

SPAN(38) = 0.0

SPAN(39) = 0.0

SPAN(40) = 0.0



| I | Y | Z | YPR | ZPR | SPAN(I) |
|----|-----------|-----------|-----------|-----------|----------|
| 1 | 2.161354 | 0.057184 | 2.000000 | 0.052099 | 2.162113 |
| 2 | 4.326030 | 0.154977 | 4.000000 | 0.135401 | 2.166905 |
| 3 | 6.493771 | 0.334096 | 6.399998 | 0.324254 | 2.175280 |
| 4 | 8.667541 | 0.503478 | 8.400000 | 0.554682 | 2.190565 |
| 5 | 10.844317 | 1.002817 | 10.799995 | 0.992337 | 2.213699 |
| 6 | 13.002581 | 1.627934 | 12.973948 | 1.617520 | 2.248323 |
| 7 | 15.106862 | 2.559123 | 14.973948 | 2.487440 | 2.303361 |
| 8 | 17.067734 | 3.912447 | 17.059357 | 3.905701 | 2.387387 |
| 9 | 18.794434 | 5.734756 | 18.687378 | 5.599998 | 2.514391 |
| 10 | 20.225235 | 8.012792 | 20.219101 | 6.000000 | 2.695131 |
| 11 | 21.329575 | 10.739202 | 21.286606 | 10.599998 | 2.944719 |
| 12 | 22.042709 | 13.941499 | 22.012314 | 13.750000 | 3.283364 |
| 13 | 22.394119 | 17.685715 | 22.390610 | 17.599976 | 3.762891 |
| 14 | 22.429413 | 21.366409 | 22.430832 | 21.799973 | 4.181564 |
| 15 | 22.343796 | 25.239594 | 22.343796 | 25.239594 | 3.374258 |
| 16 | 18.769989 | 25.486084 | 18.992035 | 25.471085 | 3.582268 |
| 17 | 15.756542 | 25.682541 | 15.863767 | 25.675858 | 3.019855 |
| 18 | 12.798687 | 25.856140 | 12.959067 | 25.847382 | 2.962949 |
| 19 | 9.862784 | 25.002213 | 10.054372 | 25.993622 | 2.939541 |
| 20 | 6.943064 | 26.115402 | 7.149673 | 26.108582 | 2.921926 |
| 21 | 4.035593 | 26.191559 | 4.244977 | 26.187378 | 2.908485 |
| 22 | 1.136441 | 26.228058 | 1.340280 | 26.226822 | 2.899400 |
| 23 | 0.0 | 0.0 | 0.0 | 0.0 | 1.136448 |
| 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | .0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 28 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 32 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 34 | 0.0 | .0.0 | 0.0 | 0.0 | 0.0 |
| 35 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 36 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 37 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 38 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 39 | 0.0 | 0.0 | 0.0 | 0.0 | - 0.0 |
| 40 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |



- 6635.875000 IN**2 FT**2 11 REQUIRED MOMENT OF INERTIA

ACTUAL MOMENT OF INERTIA =

79760.437500 IN**2 FT*

MAX. TOLERABLE STICRK = 7.9299994 TONS PER SQ. INCH

ACTUAL STICRK =12.9492407 TONS PER SQ. INCH

MAX. TULERABLE STICRD = 6.0000000TUNS PER SQ. INCH

ACTUAL STICRD = 8.3842268 TONS PER SQ. INCH

DIAL WEIGHT = 1.2419310 10NS PER FOOT LENGTH

TOTAL WEIGHT = 2781.9257812 POUNDS PER FOUT LENGTH

357.3750000 PUUNDS PER FOOT LENGTH PLATING WEIGHT = 1766.4226074 PUUNDS PER FOOT LENGTH LONGITUDINAL WEIGHT = 658.1281738 POUNDS PER FUJT LENGTH TRANSVERSE FRAME WEIGHT =

NEUTRAL AXIS IS 13.9384232 FEET ABOVE BASE LINE

SELECTED--CRUSS-SECTION AREA IS 4.3221197 SQ. IN. AND WEB DEPTH IS KEEL HAS AN AREA UF20.6864166 SQ. IN. AND A WEB UEPTH UF 24.0000000 INCHES. SCANTL ING

9.0000000 INCHES.

SELECTED PLATING THICKNESS = 0.343750 INCHES.

DESIGN REPEATED WITH THI INCREASED



B. MAIN PROGRAM COSTDATA

1. DESCRIPTION

Introduction

Main program COSDATA carries out the cost calculation for the midship section of DD-931, using as inputs much of the design information generated by program RUNSCORE.

Materials cost data, extracted from [3], are combined with various handling and erection costs to generate a total cost, per foot length of midship section, for the construction of DD-931 primary hull structure.

For reference purposes, the acquisition cost data for HTS structural members are listed in Table IV on the following pages. These members, when procured through the Federal supply system, are not discounted in price for quantity acquisitions.

The methods used by the cost estimators of the Boston Naval Shipyard were employed in main program COSDATA. All these charges are based on the cost of one man-hour of work, including yard overhead. For the purposes of this investigation, one man-hour has been arbitrarily assumed to cost \$7.50.

Main program COSTDATA takes the series of intervals



TABLE IV

AVAILABLE PLATES AND SHAPES DESCRIPTION AND ACQUISITION COSTS

| Plates | | | | | | | |
|-----------------------|----------------------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------------|------------------------------------------------------------------------------|--|--|--|
| | 1 H. O. O. O. | | | | | | |
| Thickness (Inches) | Width (Ft.) | Length (Ft.) | Cost Total | Cost Sq. Ft. | | | |
| 0.25 | 0001 | 20 29 | \$ 169 274 | \$ 1.058 1.181 1.28 | | | |
| 0.28125 0.3125 | 2868 | 20 29 29 29 29 29 20 20 | 305 238 | 1.316 1.37 1.522 | | | |
| 0.34375 0.375 | 8 8 5 | 29 20 20 | 383 254 161 | 1.587 1.61 | | | |
| 0.4375 0.50 | 80500000000000000000000000000000000000 | 29 29 330 29 29 30 29 30 29 30 16 20 | 128 3258 3534 1681 2559 5259 5351 5351 5351 | 1.618 1.652 2.264 2.158 2.37 2.375 2.462 2.796 2.984 | | | |
| 0.625 | 6 8 5 | 29 33 20 | 483 818 306 532 959 614 | 1 3.00 | | | |
| 0.75 | 88 | 33 | 959 | 3.06 3.635 3.84 3.905 | | | |
| 0.875 | 8 6 8 | 16 20 29 | 500 498 1030 | 4.15 | | | |
| 0.9375 1.00 | 15858 | 29 25.16 20 20 20 20 29 | 1958 720 725 481 1233 | 5.19 4.50 4.53 4.81 5.32 | | | |



TABLE IV - Continued

Shapes*

| No. | Depth (In.) | Flg. Width (In.) | Weight (Lb./Ft.) | Cost Per Ft. |
|-----------|--------------------------------------------|--------------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------------------------------|
| 123456789 | 6 8 8 9•9 12 16 18 24 | 4 6.063 4 5.36 5.75 4 7 7.5 12 | 12.0 22.6 13.0 20.00 21.0 16.5 40.0 50.0 | \$ 2.00 2.40 1.40 2.40 2.70 2.30 3.90 5.50 9.00 |

^{*}All shapes have a length of 40 feet.



between longitudinals for half the midship section and generates a set of intervals for the entire section. This is designed to facilitate the later calculation of butt locations to insure a clearance of at least four inches between any given butt joint and a longitudinal-plating intersection.

The cost of welding any of the various possible size plates is calculated, using the input value of cost of butt welding the given thickness of shell plating (man-hours per foot length of weld).

| Plating Thickness (Inches) | Cost of Butt Weld[4]* (Man-Hours per Foot) |
|----------------------------|--------------------------------------------|
| 0.25 | 0.38 |
| 0.28125 | 0.43 |
| 0.3125 | 0.48 |
| 0.34375 | 0.53 |
| 0.375 | o <u>.</u> 58 |
| 0.4375 | 0.68 |
| 0.50 | 0.76 |
| 0.625 | 1.22 |
| 0.75 | 1.60 |
| 0.875 | 2.02 |
| 0.9375 | 2,22 |
| 1.00 | 2.42 |

The program next calculates the number of plates required to go around the girth of the midship section. The alternate plate sizes of the appropriate thickness must be arranged in ascending order of cost per square foot area. The first plate is centered over the keel, and successive plates are added in progression around the girth of the midship section. Should a conflict arise in that a butt

^{*}This information is for work on board ship under difficult conditions. Other conditions are normal and complex.



joint is too near to a longitudinal-plating intersection, the algorithm first attempts to select the next available plating size. If this proves to be impossible, then a cut of 0.7 feet is made from the end of the plate. The following charges are made for cutting plates:

| Plating Thickness (Inches) | Cost of Cut* (Man-Hours per Foot) | Type Cut | |
|----------------------------|-----------------------------------|-------------|-----|
| 0.25 | 0.05 | Flame | cut |
| 0.375 | 0.06 | Flame | cut |
| 0.50 | 0.07 | Flame | cut |
| 0.625 | 0.08 | Flame | cut |
| 0.75 | 0.09 | Flame | cut |
| 0.875 | 0.10 | Flame | cut |
| 1.00 | O.II | Flame | cut |

The net cost of butt welding the plates is next calculated, given the total number of plates of each individual size employed in the midship section structure. The
cost of any plate cuts is calculated, using the previously
listed cost data per cut per foot plate length.

The cost of rolling the plates, using average manhour charges allocated by the Boston Naval Shipyard, based on a plate length of twenty feet, is computed next. The standard charges for such plates (twenty feet long) are as follows:

| Plating Thickness | Cost of Rolling |
|-------------------|-----------------------|
| (Inches) | (Man-Hours per Plate) |
| 0.25 | 2.9 |
| 0.50 | 2.9 |
| 0.75 | 3 ••9¹ |
| 1.00 | 3 - 9 |
| | |

^{*}Information provided by Mr. Joseph Palange, a Planner and Estimator with the Boston Maval Shipyard.



Typical rigging costs are evaluated, using an arbitrarily specified "mix" of staging comprising two platforms twenty feet high, two fourteen feet high, two eight feet high, and two three feet high. Again, normal Boston Naval Shipyard charges based on staging five feet long are evaluated on the basis of the per-foot length costs.

The acquisition cost of the plating is computed, using the input data provided the program and the determined number of plates employed of each given size.

The expense involved in the procurement, cutting, and welding of longitudinal wide flange sections is next calculated. The previously defined cost criteria for plate cutting are used for evaluating the expenses involved in cutting the shape flanges. Next, the cost of welding the longitudinals is evaluated, using normal Boston Haval Ship-yard charges similar to those described in terms of the cost of butt welds:

| Longitudinal | Welding Cost |
|---------------------------------|----------------------|
| Number | (Man-Hours per Foot) |
| 1 | 0.34 |
| 2 | 0.50 |
| .3° | 0•.3 ¹ + |
| $\frac{\mathbf{L}}{\mathbf{L}}$ | 0.42 |
| 5" | 0.42 |
| 6. | 0 • 3 ¹ + |
| 7 | 0.66 |
| 8 | 1.04 |

Additionally, for all welding operations, certain. fixed charges are added. These allow for making ready



and putting away equipment, wire brushing, arc air, dye penetrant for weld inspection, and strip heaters for heat treating welds.

An approximate evaluation of the cost contribution of the transverse frame structure is made, estimating that the cost of the transverse frame, on the average, is seventy per cent that of the centerline vertical keel, per foot length.

Once all these individual costs are calculated, the total cost of the midship section structure, per foot length, is determined.

Inputs

| Symbol | Meaning |
|---------|-------------------------------------------------------------------------|
| CWLD1/H | Cost of butt weld. (Man-Hours |
| THL | per foot length) Plating thickness. (Inches) |
| XLGTNL | The number of longitudinals in |
| CHGMNH | the midship section. The cost of one man-hour of |
| COSTKL | work. (Dollars) The total cost of the keel |
| | structure. (Dollars per foot length) |
| TOTSPN | The total midship section girth. (Feet) |
| CROLL | The cost of rolling a plate twenty feet long. (Dollars) |
| CSTLGL | The acquisition cost of a longitudinal. (Dollars per foot |
| CDAM(T) | length) |
| SPAN(I) | The interval to longitudinal (I). (Feet) |
| CWLGTL | The cost of welding a longitudi- nal. (Man-Hours per foot length) |



| Symbol | Meaning |
|----------|-------------------------------------------------------------------------|
| PLT(I,1) | Width of plate(I). (Feet) |
| PLT(I,2) | Length of plate(I). (Feet) |
| PLT(I,3) | Cost of plate(I). (Dollars) |
| CLGCUT | The cost of cutting the flanges of a longitudinal. (Man-Hours per foot) |
| FRM | Transverse frame spacing. (Feet) |

Calculated Items

| Symbol | Meaning |
|-------------|-----------------------------------------------------------------------------------------|
| TSPAN(I) | Span between longitudinals, for |
| CWELD(I) | entire section. (Feet) Cost of welding the plating, per butt per foot length. (Dollars) |
| DIST | Location of plate butts. (Feet) |
| DSUMS | Locations of longitudinals. (Feet) |
| LGL1/XLGL15 | Number of plates (1)(5) required for midship section. |
| NOCUT/PTCUT | Number of times plates must be cut. |
| CPLTWD | Total cost of welding the plating, per foot length. (Dollars) |
| CPTCUT | Total cost of cutting the plates, per foot length. (Dollars) |
| TCROLL | Total cost of rolling the plates, per foot length. (Dollars) |
| CRIG | Total cost of providing the rigging, per foot length. (Dollars) |
| CPLTNG | Total acquisition cost of the plating, per foot length. (Dollars) |
| CTLGTL | Total acquisition cost of the longitudinals, per foot length. (Dollars) |
| CWLTNL | Total welding cost for the lon- gitudinals, per foot length. (Dollars) |



Symbol Meaning The calculated cost of cutting CCUTFT the flanges of the longitudinals. (Dollars per foot length) Approximate cost per foot hull length for the transverse CTFRAM frame. (Dollars)

Output

Meaning Symbol .

CTOTAL Total cost of building the midship section, per foot length. (Dollars)

(Computer test run) Sample Input/Output

Output: CTOTAL 1466.77

| Input: | PLT(I,1) | PLT(I,2) PLT(I,3) |
|--------|----------------|-----------------------------------------|
| • | I = 1 8.0' | 33.0 959.00 |
| | 2. 8.0 | 20.0 614.00 |
| | 3 ••• | • • • • |
| | 3 ··· 5 ··· | • • • • • • • |
| | , , , , | • • • • • • • • • • • • • • • • • • • • |
| | CWLDMH 1.60 | Man-Hours/Foot |
| | THI 0.75 | Inches |
| | XLGTNL 17.0 | |
| | CHGMNH 7.50 | Dollars/Man-Hours |
| | COSTKL 27.56 | |
| | TOTSPN 125.95 | |
| | CROLL 3.90 | Dollars |
| | CSTLGL 3.90 | Dollars/Foot |
| | SPAN(I) | |
| | I = 1 4.717 | 4.751 4.853 |
| | I = 4 5.110 | 5.724 6.935 |
| | I = 5 8.516 | 9.080 13.291 |
| | CWLGTL 0.66 | |
| | CLGCUT 0.14 | |
| | FRM 8.00 | Feet |
| | | |

Fundamental Equations

CWELD(I) = CHGANH x ((2 x (PLT(I,1) + PLT(I,2))) x(CWLDMH x 1.12 + 0.144) + 5.5) 2.0 x PLT(1,2)

Dollars



DIST = DIST + PLT(I,1)

OR

= DIST - 0.7 + PLT(I+1,1)
(If too near a longitudinal)

CPLTWD = CWELD(1) x XLGL1 + CWELD(2) x XLGL2 + CWELD(3) x XLGL3 + CWELD(4) x XLGL4 + CWELD(5) x XLGL5

CPTCUT = PTCUT x CHGMM x $(0.05 + \frac{0.01 \times (THI - 0.25)}{0.125})$

TCROLL = CHGNNH x CROLL x (XLGL1 + XLGL2 + XLGL3 + XLGL4 + XLGL5)

CRIG = $0.4 \times (20. + 12.4 + 9.7 + 7.5) \times CHGMMH$

 $CPLTNG = \frac{PLT(1,3) \times XLGL1}{PLT(1,2)} + \frac{PLT(2,3) \times XLGL2}{PLT(2,2)} +$

 $\frac{\text{PLT}(3,3) \times \text{XLGL3}}{\text{PLT}(3,2)} + \frac{\text{PLT}(4,3) \times \text{XLGL4}}{\text{PLT}(4,2)}$

PLT(5,3) x XLGL5 PLT(5,2)

CTLGTL = XLGTNL x CSTLGL

CCUTFT = CLGCUT x XLGTNL x CHGNNH

 $CTFRAM = \frac{0.7 \times COSTKL \times TOTSPM}{FRM}$

CTOTAL = CPLTWD + CPTCUT + TCROLL + CRIG + CPLTNG + CTLGTL + CWLTNL + CCUTFT + CTFRAM + COSTKL

Sample Calculation (Refer to program listing, flow chart, and printout of typical computer run, following pages)



```
MAIN
G LEVEL O, Id.) (
                                          DATE = 67128
                                                              19/35/58
       DIMENSION PLT(5,3), SPAN(40), (SPAN(30), UNELD(5)
       00 860 I = 1, 80
   800 \text{ ISPAN(I)} = 0.0
   900 FURMAT (8F10.0)
       DATA LGL1, LGL2, LoL3, LGL+, LGL5, NOCUT/1, C, C, C, 2/
   910 FURMAT (8110) __
       00 \ 400 \ I = 1, 5
       READ (5, 900) PLI(I,1), PLI(1,2), PLI(I,3) ....
       write (6, 900) PLT(1,1), PLT(1,2), PLT(1,3)
      - IE (PLT(I,1) .LT. 20.0) GO TO 400
       PLI(I,1) = 0.0
       PLI(1,2) = 0.0
       PLT(I,3) = 0.0
   400 CONTINUE
       READ (5,900) CWED 4H, THI, XEGINE, CHGMNH, COSTKE, TUTSPN, CROLE, CSTEGE
       WRITE(6,9001 CALDMH, TH1, XEGINE, CHGMMH, COSTKE, TOISPN, CROLL, CSTEGE
       DU 410 I = 1, 36, 5
      READ (5,9001 SPAN(I), SPAN(I+1), SPAN(I+2), SPAN(I+3), SPAN(I + 4)
   410 MRITE(5,900) SPAN(I), SPAN(I+1), SPAN(I+2), SPAN(I+3), SPAN(I + 4)
    READ(5,900) CWLGTL, CLGCUT, FRM
       WRITE (6, 900) CHLGTL, CLGCUT, FRA
      20.420 I = 1, 40
       TSPAN(I) = SPAN(I)
      IF(SPAN(I) .EQ. U.C. GO TO 425
   420 CONTINUE
   425 IF (I .EQ. 40) GU [0.425
       00 \ 430 \ J = 1, 40
       ISPAN(I + J - I) = SPAN(I - J)
       IF ((I-J-1) .EQ. 0) GU TO 435
   430 CONTINUE
   426 \ 00 \ 431 \ J = 1, 40
   C
    CALCULATE THE COST OF WELDING THE PLATING (PER BUTT PER FT. LGTH.)
 C
 435 00 440 I = 1, 5
       IF (PLT(1,1) .EQ. 0.0) GO TO 445
   14) + 5.5)/(PLI(I,2)*2.0)
   _{445} DO 446 J = I, 5
   446 CNELD(J) = 0.0
 C
      CALCULATE THE NUMBER OF PLATES OF EACH SIZE USED FOR THE MIDSHIP
 C
       _D.SUMS _=_ 0 . C _
       1 = 1
       J = 1
```



455 DIST = DIST - 0.7 + PLT(1,1)

LGL1 = LGL1 + 1

NDCUT = NUCUT + 1

J = J + 1

GU TH 460

470 J = J + 1

LGL2 = LGL2 + 1

GU TH 460

472 DIST = DIST + PLT(1,1)

J = J + 1 LGL2 = LGL2 + 1 GO TO 460



```
G LEVEL D. MUD C
                           MAIN
                                               DATE = 67128
                                                                     19/35/58
    475 \text{ DIST} = \text{DIST} - \text{C.7} + \text{PLT(1.1)}
        NOCUT = NUCUT + 1
        LGL2 = LGL2 + 1
        J = J + 1 - - -
        GU TU 460
   480-J = J+1---
        LGL3 = LGL3 + 1
       _G0 I0 460_____
    482 \text{ JIST} = \text{DIST} + \text{PLT}(1,1)
     J = J + 1
        LGL3 = LGL3 + 1
     --- GU JU 460
    485 DIST = DIST - 0.7 + PLT(1,1)
    ___NUCUT = NUCUT + 1
      LGL3 = LGL3 + 1
      __J = _J + .1 . .....
       GO TO 460
    410 J = J + 1
        LGL4 = LGL4 + 1
     ____GU TO 450. ____
    492 \text{ DIST} = \text{DIST} + \text{PLT}(1,1)
    ____J = _J + _l
        LGL4 = LGL4 + 1
       GU TO 460___
    495 DIST = DIST - 0.4 - 0.3 + PLT(1,1)
    NUCUI = NUCUI + 1
        LGL+ = LGL4 + 1
     ......J =...J +. .1.
       GU TO 460
    510. J = J + 1
      LGL5 = LGL5 + 1 ·
G0_T0 460.
    512 DIST = DIST + PLT(1,1)
                                 and was a second a great major, which were not not seek as I have a later than a to the property of the total seek.
    LGL5 = LGL5 + 1
        J = J + 1
        GO JO 460.
    515 \text{ DIST} = \text{DIST} + \text{PLT}(1,1) - 0.7
    NOCUT = NOCUT + 1
       ..J = J + 1
        GO TO 460
    600 NUCUT = NUCUT + 1
        XLGL1 = LGL1
       _{XLGL2} = _{LGL2}
        XLGL3 = LGL3
       _XLGL4_=_LGL4_
        XLGL5 = LGL5
        CPLIND = CWELD(1)*XLGL1 + CWELD(2)*XLGL2 + CWELD(3)*XLGL3 +
```

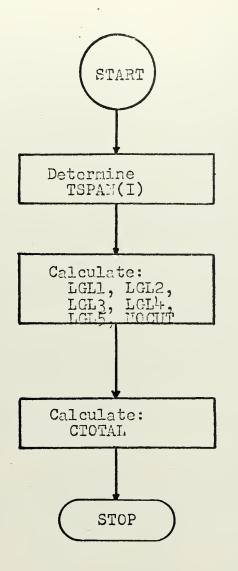


```
G LEVEL O, MUD O
                            MAIN
                                               DATE = 67128
                                                                     19/35/53
       10WELD(4) *xLULA + C/ELD(5) *XLULS
 C
 C
        DETERMINE THE CUST OF CUTTING THE PLATES.
       PICUI = NOCUT
       CPICUT = PICUT * CHGMNH * (0.05 + .C.01*((TH1-C.25)/0.125))
 C
       DETERMINE THE COST OF ROLLING THE PLATES.
 C
 C
       TORDLE = CHGANH *_CROLL *_(XEGL1+XEGL2+XEGL3+XEGL4+XEGL5)/20.0
 C
       CALCULATE THE COST OF PROVIDING STAGING.
 C
       HEIGHT OF 20', 14', 8', AND 3', TWO EACH, ARE PROVIDED.
 C
       CRIS = 0.4 * (20.0 + 12.4 + 9.7 + 7.5) * CHGMNH
 C
       NOW CALCULATE THE ACQUISITION COST FOR THE PLATING.
 C
       CPL TAG = PLT(1,3) * XLGL1/PLT(1,2) + PLT(2,3) * XLGL2/PLT(2,2) +
      1 PLT(3,3)*XLGL3/PLT(3,2) + PLT(4,3)*XLGL4/PLT(4,2) +
      2 PLT(5,3)*XLGL5 / PLT(5,2)
 C
       NOW CALCULATE THE ACQUISITION COST FOR THE LONGITUDINALS.
 C
 C
       CTEGTE = XEGTNE * CSTEGE
 C
 C
       CALCULATE THE WELDING COST FOR THE LONGITUDINALS.
 C
       CWLTNL = XLGINL * CHGMNH *(CWLGTL*1.12 + 0.151)
 C
       CALCULATE THE COST OF CUTTING THE FLANGES OF THE LONGITUDINALS.
 C
 C ...
       COUTET = CLGCUT * XLGTNL * CHGMNH
 C
 C
       CALCULATE THE APPROXIMATE COST (PER FOOT HULL LENGTH) FOR THE TRANSVET
       ERAME. ESTIMATE IMAI, PER FI. GIRTH, CFRAME = 0.7 * COSTKL.
 C
      _CTERAM = _0.7 * COSTKL * TOTSPN / FRM
 C
      CALCULATE THE TUTAL COST OF BUILDING THE MIDSHIP SECTION, DOLLARS
 C
 C
       PER FOUT HULL LENGTH.
       CTOTAL = CPLTWD + CPTGUT + TCRULL + CRIG + CPLTNG + CTLGTL +
      1 CWLINE + COUTFT + CTFRAM + COSTKL
   920 FORMAT ('1 CPLINO =',F15.6)
   921 FORMAT ('C CPTCUT =1,E15.0)
922 FORMAT ('C TCRULL =',F15.0)
  _921 FORMAT ('C
                     CPTCUT = 1, E15.0)
   923 EURMAI (10 CRIG = 1, F15.5)
```



```
G LEVEL D, MUD D
                            MAIN
                                               DATE = 67128
                                                                    19/35/58
   924 FURMAT (1)
                     CPLTN3 =1, F15.6)
   925 FORMIAT (16
                     CILGIL = 1, F15.6)
    920 FOR 1AT (10
                      CALTAL = 1, F15.6)
    927 FOR WAT (10
                    CCUTFT = ',F15.6)
    928 FUR AAT (10
                     CTFRAM = 1, F15.6)
   929 FORMAT (10
                     CTOTAL =1,F15.6)
                     LGL1 = ', I2, ' LGL2 = ', I2, ' LGL3 = ', I2, ' LGL4 = ',
    930 FORMAT ( '0
      1 12, ' LGL5 = ', 12)
                     KLGL1 =',F5.2,' XLGL2 =', F5.2,' XLGL3 =', F5.2,'
   931 FORMAT (10
       1xLGL4 = 1, F5.2, 1 XLGL5 = 1, F5.21
    932 FOR TAT ('0 CNELD(I) =',5(F8.3,5X))
     -- WRITE (6, 932) CARLO(1), CWELD(2), CWELD(3), CWELD(4), CMELD(5)
        WRITE (5, 920) CPLIND
       WRITE (a, 921) CPTCUT
        WRITE (6, 922) TORULE
       WRITE (6, 923) CRIG .-
       wRITE (6, 030) LGL1, LGL2, LGL3, LGL4, LGL5
        ARITE 16, 9311 XLGL1, XLGL2, XLGL3, XLGL4, XLGL5
       WRITE (6, 924) CPLING
       WAITE (5, 925) CIEGIL
       WRITE (6, 926) CHLTNL
       ARITE_(6, 927) COUTFI
        WRITE (6, 923) CIERAM
       WRITE (6, 929) CTUTAL
       STOP
        ENO.
```





Generate an array of longitudinal intervals for the entire midship section.

Locate plates around the girth, assuring no conflicts with longitudinals. Cut plates if necessary.

Determine the total cost of building the midship section.

FIGURE IV

MAIN PROGRAM COSTDATA FLOW CHART



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| 28 | DIST, | SUMS, | J, Loll | , LGL2, LG | 13, LGL4 | ,LGL | , NOCUT | | | 0 | | - 1 |
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| 60 | DIST, DSUMS | , J, LGL1 · LUI 76 · 260376 | 2,LGL3, | LGL4, LGL | .5,400UT | 0 | 0 | 0 | 2 |
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C. SUBROUTINE TSLECT

1. DESCRIPTION

Introduction

Given the minimum tolerable spacing of longitudinals and the design stress criteria, this subroutine calculates the required plating thickness using criteria for the critical stress and tertiary stress levels. These two thicknesses are then compared, and the greater selected. This exact value of thickness is then used to select the minimum standard plate thickness that will satisfy the design requirements, and the minimum spacing is modified by the ratio of the selected thickness to the required thickness. This span is then used as the initial longitudinal spacing.

Inputs

| Symbol | Meaning |
|--------|--------------------------------------------------|
| W5BMIN | Minimum permissible longitudinal spacing. (Feet) |
| STICRK | Maximum permissible stress at keel. (Tons/In.2) |
| ST2EST | Estimated value of secondary stress. (Tons/In.2) |
| SCHULT | Yield stress of the plating. (Tons/In.2) |
| FRM | Transverse frame spacing. (Feet) |



Calculated Items

| Symbol | Meaning |
|--------|----------------------------------------------------------------------------------------------------------------|
| SGMACR | Limiting stress intensity, defined as 1.25 x (STICAL + ST2EST) (Tons/In.2) |
| ABAB | Plate aspect ratio. |
| ClCRIT | Coefficient used in calculating the critical strength of the plating. |
| CCL | Intermediate calculation used in determining the required plating thickness based on critical stress criteria. |
| THPRIM | Plating thickness required to satisfy critical stress criteria. (Inches) |
| PRESS | Hydrostatic pressure at keel. (Tons/In.2) |
| C3CRIT | Coefficient used in calculating the tertiary stress strength of the plating. (Tons/In. 2) |
| ST3MAX | Maximum tolerable intensity of the tertiary stress. (Tons/In.2) |
| CC3 | Intermediate calculation used in determining the required plating thickness based on tertiary stress criteria. |
| THTER | Plating thickness required to satisfy tertiary stress criteria. (Inches) |
| TH | The greater of THPRIM or THTER. (Inches) |

Output

| Symbol . | Meaning |
|----------|------------------------------------------------------------------------------------------------------|
| THI | Plating thickness selected. This is the least existing thickness that exceeds the value TH. (Inches) |
| W5BACT | Tolerable longitudinal spacing for selected plating thickness. (Feet) |

Calling Sequence

Call TSLECT (W5BMIN, STICRK, ST2EST, SGMULT, FRM, THI, W5BACT)



Sample Input/Output

(Computer test run)

| Input: | W5BMIN STICRK ST2EST SGMULT FRM | 1.667 7.93 1.34 20.98 8.00 | Feet. Tons/In.2 Tons/In.2 Tons/In.2 Feet |
|---------|---------------------------------------------|----------------------------------------|------------------------------------------|
| Output: | THL | 0.28125 | Inches |

I.769

Fundamental Equations

$$ABAB = \frac{FRM}{W5BNIN}$$

W5BACT

$$CC1 = \sqrt{\frac{C1CRIT \times 3.1416^2 \times 13392.857}{10.9 \times SGIACR}}$$

Feet

THPRIM =
$$\frac{12.0 \times W5BMIN}{CC1}$$

$$PRESS = \frac{0.44.5 \times HM}{2240.}$$

$$CC3 = \sqrt{\frac{ST31AX}{5.46 \times C3CRIT \times PRESS}}$$

THTER =
$$\frac{12 \times \text{W5BMIN}}{\text{CC3}}$$

Sample Calculation

(Refer to subroutine listing and flow chart, following pages)

$$ABAB = 4.80$$

$$CC1 = \sqrt{\frac{(7.225 \times 9.87 \times 13392.857)}{126.4}}$$
= 86.9

THPRIM =
$$\frac{20}{86.9}$$

= 0.230

$$HM = 30.23$$



PRESS =
$$0.00601$$

$$C3CRIT = 0.0627$$

$$ST3MAX = 11.71$$

$$cc_3 = \sqrt{\frac{11.71}{5.46 \times .0627 \times .00601}}$$
$$= 75.7$$

THTER =
$$\frac{20}{75.7} = 0.264$$

$$TH = 0.264$$

THL =
$$0.28125$$
 inches

THI =
$$0.28125$$
 inches

W5BACT = 0.28125 x 1.667

= 1.77 feet



```
SUBROUTINE TSLECT( #58MIN, STICRK, STZEST, SGMULT, FRM, TH1, W58ACT)
      SGMACR = 1.25 * (STICRK + STZEST)
      ABAB = FRM / W53MIN
      IF (ABAS - 7.0) 701, 703, 703
  703 \ C1CRIT = 7.0
      GO TO 780
  701 IF (ABAB - 3.5) 702, 704, 704
  704 \text{ CICRIT} = 7.0 + 0.4 * ((7.0 - ABAB)/3.5)
      GO TO 780
  702 IF(ABAB - 1.9) 705, 706, 706
  706 CICRIT = 7.4 + 0.7 = (3.5 - ABAB)/1.6
      GO TO 780
  705 CICRIT = 8.1 - (ABAB - 1.9) / 1.9
  780 ADULIN = CICRIT * 3.1416 * 3.1416 * 13392.86
      BDULIN = 10.9 * SGMACR
      CC1 = SQRT (ADULIN/BDULIN)
      STICAL = STICRK
      THPRIM = (\%53MIN * 12.) / CC1
      YPTMIN = 0.0
      ZPTMIN = 0.0
      TERTIARY STRESS CALCULATION
C
      A3HEEL = 0.5236
      D1 = 26.231247
      HIAMDK = 4.0
      H1DFL = 14.5
      XL1BP = 407.
      NBELTS = 1
      CALL HDWTR (A3HEEL, YPTMIN, D1, H1AMDK, H1DFL, NBELTS, XL1BP, ZPTMIN, HM)
      PRESS = (0.445 * HM) / 2240.
      IF \{A3AB - 1.4\} 901, 903, 903
  903 \ C3CRII = 0.0627
      GO TO 980
  901 IF (ABAB - 1.2) 902, 904, 904
  904 C3CRIT = 0.0015 + 0.0012 * ((ABAB - 1.2) / 0.2)
      GO TO 980
  902 C3CRIT = 0.057 + 0.0009 * (ABAB - 1.0)
  980 ST3MAX = SGMULT - ST1CAL - ST2EST
      CC3 = SQRT (ST3MAX / (5.46 * C3CRIT * PRESS))
      THIER = (12.0 * W58MIN) / CC3
      IF (THTER .GT. THPRIM) GO TO 600
      TH = THPRIM
      GO TO 16
  600 TH = THTER
   16 IF((TH - 0.375).GT. 0) GO TO 401
  405 IF ((TH - 0.25) .GT. 0) GO TO 407
      TH1 = 0.25
      GO TO 900
```



- 407 IF ((TH 0.28125) .GT. 0) GU TU 409 TH1 = 0.28125 GU JU 900
- 409 IF((TH 0.3125) .GT. 0) GO TO 411 TH1 = 0.3125 GO TO 900
- 411 IF ((TH 0.34375) .GT. 0) GO TO 413 TH1 = 0.34375 GO TO 900
- 413 TH1 = 0.375 GO TO 900
- 401 IF((TH1 1.0).GT. 0) GO TO 501 . IF((TH - 0.4375).GT. 0) GO TO 503 TH1 = 0.4375 GO TO 900
- 503 IF((TH 0.50) .GT. 0) GU TU 505 TH1 = 0.500 GO TO 900
- 505 IF ((TH 0.625) .GT. 0) GO TO 507 TH1 = 0.625 GO TO 900
- 507 IF((IH 0.75).GT. 0) GO TO 509 TH1 = 0.75 GO TO 900
- 509 IF((TH 0.875) .GT. 0) GO TO 511 TH1 = 0.875 GO TO 900
- 511 IF((TH 0.9375) .GT. 0) GO TO 513 TH1 = 0.9375 GO TO 900
- 513 TH1 = 1.000
- 17 FORMAT ('KEQUIRED PLATING THICKNESS EXCEEDS ONE INCH.')
- 501 WRITE (6, 17)
- 900 W5BACT = (TH1 * W5BMIN) / TH RETURN END



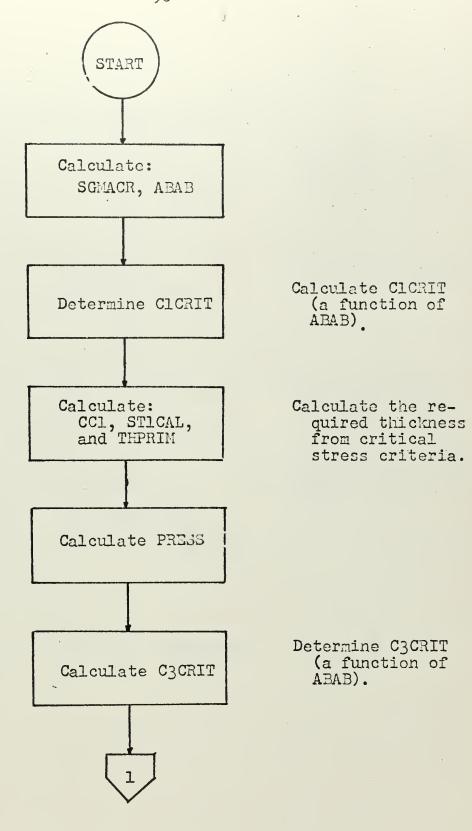


FIGURE V
SUBROUTINE TSLECT FLOW CHART



FIGURE V - Continued



D. SUBROUTINE HOWTR

1. DESCRIPTION

Introduction

This subroutine calculates the maximum hydrostatic head of water existing at a designated point on the shell. Three loading conditions are evaluated, using current procedures employed by the Naval Ship Systems Command in the design of ships:

- 1. The maximum head is calculated for the effects of the full load draft with half the height of a standard wave profile superposed.
- 2. The maximum head is calculated for the condition of the ship at full load draft heeled over some specified angle. In the case of this analysis, the heel angle is fixed at thirty degrees.
- 3. Finally, the maximum head resulting from the superposition of a specified design head of water on the main deck is computed.

Subroutine HDWTR is based on a subroutine of the same name developed by the Applied Mathematics Laboratory of the David Taylor Model Basin, Washington, D. C. 20007.



After the individual heads are determined for the various conditions, the maximum value is selected as the output from the subroutine.

| Inputs | Symbol | Meaning | | |
|------------------|---------------|----------------------------------------------------------------|--|--|
| | D VIII DOIL | Health | | |
| | A3HEEL | Specified maximum heel angle. (Radians) | | |
| | ВЗР | Half breadth of point. (Feet) | | |
| | Dl | Depth of hull. (Feet) | | |
| | HLANDK | Specified design head of water above main deck. (Feet) | | |
| | HIDFL | Design full load draft. (Feet) | | |
| | NBELTS | Number of points. (= 1) | | |
| | XL1BP | Length between perpindiculars. (Feet) | | |
| | ZKlP | Height of point above keel. (Feet) | | |
| Calculated Items | | | | |
| Carculati | Symbol Symbol | Meaning | | |
| | HMANDK | Head of water due to design head of water on main deck. (Feet) | | |
| | HAHEEL. | Head of water due to heel. (Feet) | | |
| | HMO | Head of water due to wave profile. (Feet) | | |
| | B | Draft due to standard wave profile. (Feet) | | |
| | THM | Draft due to head of water above main deck. (Feet) | | |
| Output | Symbol | Meaning | | |

Calling Sequence

HM

Call HDWTR (A3HEEL, B3P, D1, HLAMDK, HLDFL, MBELTS, XL1BP, ZK1P, HM)

Maximum head of water to point. (Feet)



Sample Input/Output (Computer test run)

| Input: | A3HEEL B3P D1 H1AMDK H1DFL NBELTS XL1BP ZK1P | 0.5236 39.83 70.00 0.00 26.00 1 580.00 14.00 | radians feet feet feet feet feet |
|---------|-------------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------|
| Output: | HM | 30.31 | fèet |

Fundamental Equations

HI = HIDFL + 0.55 x
$$\sqrt{\text{XL1BP}}$$

HMO = HI - ZKIP
HMHEEL = D x Cos (1.5708 - B - A3HEEL)
B = Arctan $\frac{\text{HIDFL} - \text{ZKIP}}{\text{B3P}}$
D = $\sqrt{\text{B3P}^2}$ + (HIDFL - ZKIP)²
HMAMDK = THM - ZKIP
THM = D1 + HIAMDK

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

HI =
$$26.00 + 0.55 \times 24.08319$$

= 39.2458

$$HMO = 39.2458 - 14.0$$

= 25.2458

$$D = \sqrt{1585.43 + 144}$$

$$= 41.53$$

HMHEEL =
$$41.53 \times \cos (0.7546)$$

= 30.31

HM = HAHEEL = 30.31 feet.



```
SUBROUTINE HOWTR(A3HEEL, B3P, D1, H1AMUK, H1DFL, NBELTS, XL1BP, ZK1P, HM)
C
C
      CALCULATE DRAFT TO STANDARD WAVE HEIGHT
C
      H1 = H1DFL + 0.55 * SQRT(XL18P)
      IF(ZK1P - H1) 1,2,2
    1 \text{ HMO} = \text{HI} - \text{ZK1P}
      GO TO 3
      0.0 = 0.0
000
      CALCULATE HEAD OF WATER DUE TO HEELED WATERLINE
    3 IF (ZK1P - H1DFL) 4,7,5
    4 D = SQRT(B3P**2 + (H1DFL - ZK1P)**2)
      IF (B3P) 19,19,18
     B = 1.5708
      GU TO 20
   18 B = ATAN ((H1DFL - ZK1P)/B3P)
   20 IF (B - 1.5708 + A3HEEL) 15, 16, 17
   15 HMHEEL = D*COS(1.5708 - A3HEEL - B)
      GO TU 10
   16 HMHEEL = D
    GO TO 10
   17 HMHEEL = D*CUS(B - 1.5708 + A3HEEL)
      GO TO 10
    5 D = SQRT (B3P**2 + (ZK1P - H1DFL)**2)
      B = ATAN ((ZK1P - H1DFL)/83P)
      IF ( B - A3HEEL) 6,8,8
    6 HMHEEL = D*COS(1.5708 - A3HEEL + B)
      GO TO 16
    7 HMHEEL = B3P * SIN(A3HEEL)
      GO TO 10
    8 HMHEEL = 0.0
C
      COMPARE HEADS CALCULATED THUS FAR AND DETERMINE THE MAXIMUM
   10 IF (HMO - HMHEEL) 11, 12, 12
   11 \text{ HM} = \text{HMHEEL}
      GO TO 100
   12 \text{ HM} = \text{HMO}
  100 CONTINUE
      IF(H1AMDK) 40,40,41
C
      CALCULATE DRAFT DUE TO HEAD OF WATER ABOVE MAIN DECK
C
   41 \text{ THM} = D1 + H1AMDK
       HMAMDK = THM - ZK1P
C
```



G LEVEL O, MOD O HOWTR

DATE = 67132 19/43/58

COMPARE HEADS AND DETERMINE FINAL MAXIMUM HEAD AT POINT

IF (HMAMDK - HM) 45,45,46

- 46 HM = HMAMDK
- 45 CUNTINUE
- 40 RETURN

END



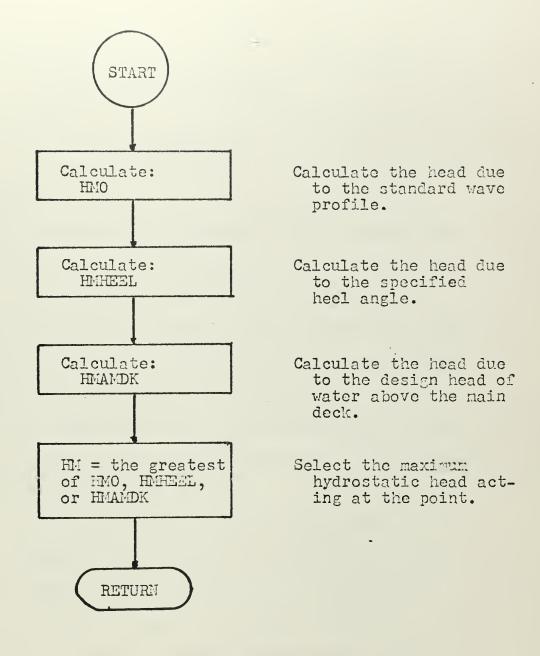


FIGURE VI SUBROUTINE HDWTR FLOW CHART



E. SUBROUTINE CSPACE

1. DESCRIPTION

Introduction

This subroutine calculates the maximum permissible span to the next (upper) longitudinal on the midship section. The hydrostatic head existing at the lower edge of the span is employed for this calculation. The permissible spacing is calculated on the basis of three different criteria, as described by St. Denis [1]:

- 1. The permissible span is calculated on the basis of the maximum compressive stress exerted on the plating.
- 2. The permissible span is calculated on the basis of the tolerable tertiary stress level caused by plate binding due to hydrostatic pressure normal to the plate surface.
- 3. Finally, stability requirements for the unsupported plate are used to evaluate the permissible span between longitudinals.

Once the three values of the tolerable span have been determined, the lesser value of the three is selected as the limiting span.



Inputs

Symbol Meaning Maximum permissible stress at keel. (Tons/In.2) STICRK ST1 CRD Maximum permissible stress at deck centerline. (Tons/In.2) ST2EST Estimated value of secondary stress. (Tons/In.2) Yield stress of the plating. SCHULT (Tons/In.2) FRM Transverse frame spacing. (Feet) THL Plating thickness. (Inches) YPTMIN Half breadth of preceding longitudinal. (Feet) Height of preceding longitudinal above base line. (Feet) ZPTMIN W5BPRC Span to preceding longitudinal. (Feet)

Calculated Items

C3CRIT

Symbol Meaning ZNAXIS Location of neutral axis of DD-931 midship section above base line. (Feet) STICAL Calculated primary compressive stress at preceding longitudinal. (Feet) Limiting stress intensity, SGMACR defined as 1.25 x (STÍCAL + ST2EST) (Tons/In.²) Aspect ratio of preceding span. ABAB CLCRIT Coefficient used in calculating the critical strength of the plating. W5BTL1 Permissible span due to critical strength criteria. (Feet) Hydrostatic pressure at pre-PRESS ceding longitudinal. (Tons/ In.2)

Coefficient used in the tertiary

stress calculation.



| Symbol | Meaning |
|--------|-----------------------------------------------------------------|
| W5BTL3 | Permissible span due to the tertiary stress calculation. (Feet) |
| SGMCRT | Critical stress intensity for a panel of plating. (Tons/In.2) |
| XNOSTF | Required number of stiffeners for a plate panel. |
| ST3MAX | Greatest tolerable tertiary stress. (Tons/In.2) |
| W5BTLS | Tolerable span on basis of plate stability criteria. (Feet) |

Output

| Symbol | Meaning | |
|--------|--------------------------------|--|
| W5BTOL | Maximum tolerab longitudina | |

Calling Sequence

Call CSPACE (STICRK, STICRD, STZEST, SGHULT, FRM, TH1, YPTMIN, ZPTMIN, W5BPRC, W5BTOL)

| Sample Input/Output | (Compute | er test run | |
|---------------------|----------------------------------------------------------|-------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| Input: | STICRK STICRD ST2EST SGMULT FRM THI YPTMIN ZPTMIN W5BPRC | 7.93 6.00 1.3 ¹ + 20.98 8.00 0.28125 1.768 0.045 1.769 | Tons/In.2 Tons/In.2 Tons/In.2 Tons/In.2 Feet Inches Feet Feet Feet |
| Output: | W5BTOL | 1.772 | Feet |

Fundamental Equations

| ZNAXIS = | 26.23125 | x (STICRK STICRD) |) |
|----------|----------|---------------------------|---|
| STICAL = | STICRK x | ZNAXIS - ZPTMIN ZNAXIS | |



$$W5BTL1 = \frac{TH1 + CC1}{12.0}$$

$$CC1 = \sqrt{\frac{C1CRIT \times 3.1416^2 \times 13392.86}{10.9 \times SGMACR}}$$

PRESS = 0.445 x FM/2240.

W5BTL3 =
$$\frac{\text{THL} \times \text{CC3}}{12.0}$$

$$CC3 = \sqrt{\frac{ST3FAX}{5.46 \text{ m C3CRIT m PRESS}}}$$

$$SGMCRT = \frac{4.0 \times 3.1416^2 \times 13392.86 \times TH1^2}{10.8 \times 3600}$$

XNOSTF =
$$\sqrt{\frac{SGNACR}{SGNCRT}}$$
 - 1.0

W5BTLS =
$$\frac{5.0}{\text{XNOSTF}}$$

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

ZNAXIS =
$$26.23125 \times \frac{7.93}{13.93}$$

STICAL =
$$7.93 \times \left(\frac{14.885}{14.93}\right)$$

= 7.90

$$CC1 = \sqrt{\frac{7.283 \times 3.1416^2 \times 13392.86}{10.9 \times 11.56}}$$
$$= 87.5$$

$$W5BTL1 = \frac{0.28125 \times 87.5}{12.0}$$
$$= 2.05$$

PRESS =
$$0.14+5 \times 30.19/221+0$$

= 0.006

$$ST3MAX = 11.74$$



$$cc_3 = \sqrt{\frac{11.74}{5.45 \pm .0627 \times .006}}$$

$$= \frac{75.7}{45.45 \pm .0627 \times .006}$$
W5BTI3 = 0.28125 x 75.7

W5BTL3 =
$$0.28125 \times 75.7$$

12.0 = 1.772

$$SGMCRT = 1.076$$

XNOSTF =
$$\sqrt{\frac{11.56}{1.076}}$$
 - 1.0 = 2.28

W5BTLS =
$$2.245$$



SUBROUTINE CSPACE (STICRK, STICRD, STZEST, SGMULT, FRM, THI, YPTMIN,

```
0000000000
```

G LEVEL O, MOD O

```
1ZPTMIN, W5BPRC, W5BTUL)
    W5bTOL IS CALCULATED ON THE BASIS OF THE PRIMARY AND TERTIARY
    STRESSES. THE LESSER VALUE OF THE TWO IS THEN SELECTED.
   THIS VALUE OF WESTUL IS THEN COMPARED WITH THE MINIMUM SPAN
    PERMITTED ON THE BASIS OF THE REQUIRED NUMBER OF STIFFENERS FOR A
   PLATE WITH THICKNESS THE AND A WIDTH OF 5.0 FFFE.
    BASIC METHODOLOGY OF SUBROUTINE ISLECT IS USED FOR THE PRIMARY STRESS
   CALCULATION.
    ZNAXIS = 26.23125 * (STICRK / (STICRK + STICRD))
    STICAL = STICRK * ABS ((ZNAXIS - ZPTMIN)/ZNAXIS)
    SGMACR = 1.25*(STICAL + STZEST)
    ABAB = FRM / W58PRC
    IF (ABAB - 7.0) 701, 703, 703
703 \text{ C1CRIT} = 7.0
    GO TO 780
701 IF (ABAB - 3.5) 702, 704, 704
704 \text{ C1CRIT} = 7.0 + (0.4*((7.0-ABAB)/3.5))
    GO TO 780
702 IF (ABAB-1.9) 705, 706, 706
706 CICRIT = 7.4 + 9.7*(3.5-ABAB)/1.6
    GO TO 780
705 \text{ C1CRIT} = 8.1 - (ABAB-1.9)/1.9
780 ADULIN = CICRIT * 3.1416 * 3.1416 * 13392.86
    BDULIN = 10.9 * SGMACR
    CC1 = SQRT (ADJLIN/BDULIN)
    W5BTL1 = (TH1 * CC1)/ 12.
    TERTIARY STRESS CALCULATION.
    DATA A3HEEL, D1, H1AMDK, H1DFL, NBELTS, XL1BP/.5236, 26.23125, 4., 14.5, 1,
   1 407./
    CALL HDATR (A3HEEL, YPTMIN, D1, H1AMDK, H1DFL, NBELTS, XL1BP, ZPTMIN, HM)
    PRESS = 0.445 * HM/2240.
    IF(ABAB - 1.4) 901, 903, 903
903 \ C3CRIT = 0.0627
    GO TO 980
901 IF(ABAB-1.2) 902, 904, 904
904 \text{ C3CRIT} = 0.0615 + 0.0012 * ((ABAB-1.2)/C.2)
    GU TU 980
902 C3CRIT = 0.057 + 0.0225 \# (ABAB-1.0)
980 ST3MAX = SGMULT - ST1CAL - ST2EST
    CC3 = SQRT (ST3MAX/(5.46 *C3CRIT*PRESS))
    W5BTL3 = TH1 * CC3 / 12.0
    IF (W5BTL1 .GT. W5BTL3) GO TO 410
```



W53TOL = W5BTL1 GO TO 600

410 W58TOL = W58TL3

0000

C

PROVIDE FOR ADEQUATE PLATE STABILITY BY LIMITING W5BTOL ON THE BASIS OF THE NUMBER OF STIFFENERS REQUIRED FOR A PLATE WITH A WIDTH OF FIVE FEET.

600 SGMCRT=4.*(3.1416**2)*13392.86*(TH1**2)/(10.8 * 3600.)

XNOSTF = SQRT (SGMACR / SGMCRT) + 1.0

W58TLS = ABS (5.0/XNOSTF)

IF (W5BTOL .LT. W5BTLS) GO TO 601

W5BTOL = W5BTLS

601 CONTINUE RETURN END



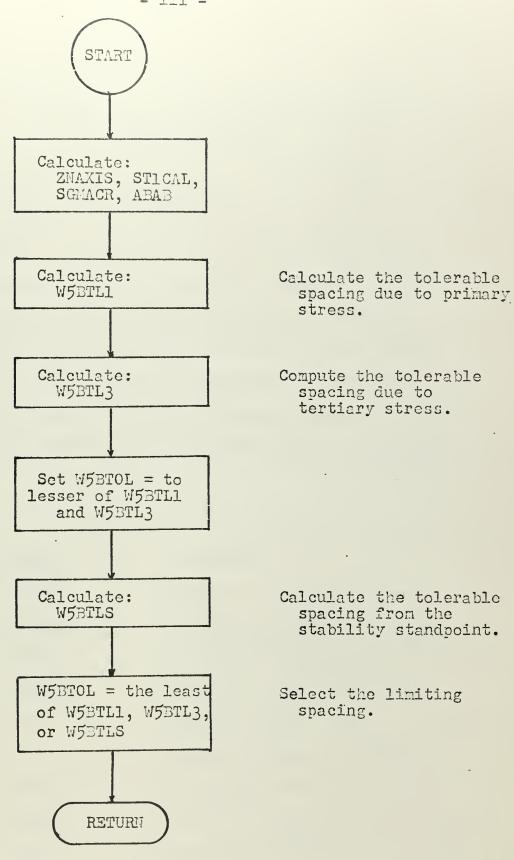


FIGURE VII
SUBROUTINE <u>CSPACE</u> FLOW CHART



F. SUBROUTINE CLONGL

1. DESCRIPTION

Introduction

Subroutine CLONGL is designed to calculate the required section modulus for the longitudinal-plating combination, as well as the minimum permissible radius of gyration. The resulting computation is concerned solely with strength criteria, as the criteria for plating-longitudinal stability are determined later in the main program.

Inputs

| Symbol | Meaning |
|--------|------------------------------------------------------------|
| STICRK | Maximum permissible stress at keel. (Tons/In.2) |
| STICRD | Maximum permissible stress at deck centerline. (Tons/In.2) |
| ST2EST | Estimated value of secondary stress. (Tons/In.2) |
| SGMULT | Yield stress of the plating. (Tons/In.2) |
| FRM | Transverse frame spacing. (Feet) |
| THL | Plating thickness. (Inches) |
| YPTLOC | Half breadth of longitudinal. (Feet) |
| ZPTLOC | Height of longitudinal above base line. (Feet) |
| W5BPRC | Span from preceding longitudinal. (Feet) |



Symbol Meaning

R5GYRA Required radius of gyration of plating-longitudinal combi-

nation. (Inches)

Calculated Items

WIDTH

Symbol Meaning

XR5GYR Calculated radius of gyration required for given longitudinal location. (Inches)

PRESS · Hydrostatic pressure at langitudinal. (Pounds/In.2)

Location of neutral axis of DD-931 ZNAXIS midship section above base line.

(Feet)

STICAL Calculated primary compressive

stress at longitudinal. (Feet) Permissible span for cases where

span exceeds 50.0 x THL.

(Inches)

Effective width of plating, dic-EWIDTH tated by the lesser of WIDTH

and 12.0 x W5BPRC. (Inches)

Bending moment at mid-span of XMBLLG

plating-longitudinal combination.

(Inch-Pounds)

ST3LGL. Tolerable level of tertiary stress. (Tons/In.2 converted to Lb./In.2)

Output

Meaning Symbol

Required radius of gyration of R5GYRA

plating-longitudinal combi-

nation. (Inches)

Required section modulus of XMD1 MN

plating-longitudinal combination. (In.3)

Calling Sequence

Call CLONGL (STICRK, STICRD, ST2EST, SGMULT, FRM, THI, WEBPRC, REGYRA, WIDIMN, YPTLOC, ZPTLOC)



Sample Input/Outcut (Computer test run)

| Input: | STICRK STICRD ST2EST SGMULT FRM THI YPTLOC ZPTLOC W5BPRC R5GYRA | 7.93 6.00 1.34 20.98 8.00 0.28125 1.768 0.045 1.769 3.097 | Tons/In.2 Tons/In.2 Tons/In.2 Tons/In.2 Tons/In.2 Feet Inches Feet Feet Feet Inches |
|---------|-----------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Output: | R5GYRA | 3.097 | Inches |
| | XMDLMN | 8.277 | In.3 |

Fundamental Equations

$$XR5GYR = \frac{12.0 \text{ x FRM}}{31.}$$

PRESS = $0.445 \times HM$

ZNAXIS = 26.23125 x
$$\frac{\text{STICRK}}{\text{STICRK}}$$
 + $\frac{\text{STICRK}}{\text{STICRL}}$ = $\frac{\text{ZNAXIS}}{\text{ZNAXIS}}$

WIDTH = 50.0 m THL

XMBLLG = 19.0 x PRESS x EWIDTH x FRM^2

ST3LGL = SGMULT - ST1CAL - ST2EST

 $ST3LGL = 2240. \times ST3LGL$

 $XMDLMN = \frac{XMBLLG}{ST3LGL}$

Sample Calculation

(Refer to subroutine listing and flow chart, following pages)

$$XR5GYR = \frac{96.}{31.} = 3.097$$

$$ZNAXIS = 26.23125 \times \frac{7.93}{13.93}$$

ZNAXIS =
$$26.23125 \times \frac{7.93}{13.93}$$

STICAL = $7.93 \times \frac{11.91}{14.91} = \frac{7.90}{14.91}$



W5BPRC = 21.23 inches

WIDTH = 14.06

EWIDTH = WIDTH = 14.06

 $XMB1LG = 18. \times 13.4 \times 14.06 \times 64.$ = 217,000

ST3LGL = 26,320 psi

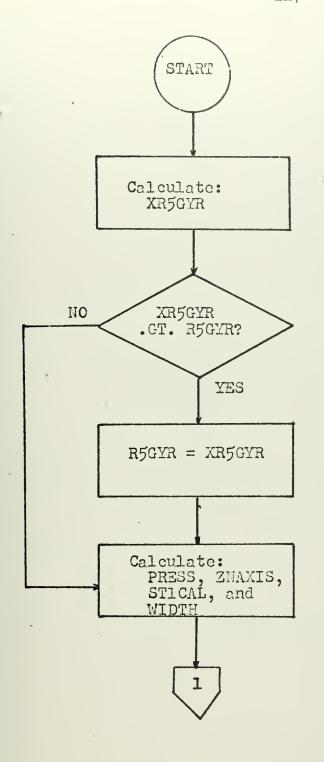
 $XMD1MN = \frac{217,000}{26,320} = 8.28$



RETURN END

```
SUBROUTINE CLUNGL( STICRK, STICRD, STZEST, SGMULT, FRM, TH1, W5BPRC,
   1 R5GYRA, XMD1MN, YPTLOC, ZPTLOC)
    XR5GYR = 12.0 * FRM / 31.0
    IF (XR5GYR - R5GYRA) 201, 203, 203
203 R5GYRA = XR5GYR
201 A3HEEL = 0.5236
    AAA = W5BPRC
    D1 = 26.231247
    H1AMDK = 4.0
    H1DFL = 14.5
    NBELTS = 1
    XL1BP = 407.
    CALL HOWTR (A3HEEL, YPTLOC, D1, H1AMDK, H1DFL, NBELTS, XL1BP, ZPTLOC, HM)
    PRESS = 0.445 * HM
    ZNAXIS = 26.231247 * STICRK / (STICRK + STICRD)
    STICAL = STICRK * ABS ((ZNAXIS - ZPTLOC)/ZNAXIS)
    W58PRC = 12.0 ★ ₩58PRC
    WIDTH = 50.0 * TH1
    IF (W53PRC .LT. WIDTH) GO TO 600
    EWIDTH = WIDTH
    GO TO 601
600 EWIDTH = W5BPRC
601 XMB1LG = 18.0 * PRESS * EWIDTH * (FRM**2)
    STALGL = SGMULT - STICAL - STZEST
    W5BPRC = AAA
    ST3LGL = 2240. # ST3LGL
    XMD1MN = XMB1LG / ST3LGL
```



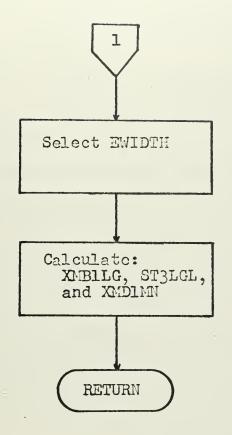


Determine the limiting value of the radius of gyration.

Do the preliminary computations for determining the effective width of plating.

FIGURE VIII
SUBROUTINE CLONGL FLOW CHART





Determine the required section modulus for the plating-longitudinal combination.

FIGURE VIII - Continued



G. SUBROUTINE PMINER

1. DESCRIPTION

Introduction

The characteristic data delineating the contribution of the half breadth plating to the total area and section modulus of the midship section were generated by subroutine WTSMOD for all available plating thicknesses, up to one inch maximum. This information is imbedded in subroutine PMINER in such a way that, given an input of the plating thickness, the appropriate information detailing the effects of the plating on the total area and section modulus is provided.

Inputs

Symbol

Meaning

THL

Plating thickness. (Inches)

Calculated Items

None. Subroutine PMINER merely selects the correct values of BLADM, AREAPT, XMOMIN, and XINER (defined below) for the given input value of plating thickness.



Output

| Symbol | <u>Meaning</u> |
|--------|--------------------------------------------------------------------------------------------------------------|
| BLMOM | Moment about the base line for the half breadth plating. (Inches Feet) |
| AREAPT | Total area for the half breadth plating. (Inches2) |
| XMOMIN | Net moment of inertia about the base line for the half breadth plating. (Inches Feet 2) |
| XINER | Moment of inertia of the total midship section plating about the neutral axis for the plating. (Inches Feet) |

Calling Sequence

Call PMINER (THI, BLOOM, AREAPT, XHOMIN, XIMER)

| Sample Input/Output | (Computer | test run) | |
|---------------------|---------------------|--------------------------------------------------|-------------------------------------------|
| Input: | THL | 0.625 | inches |
| Output: | ARMAPT XMOMIN 15 | 6883.683+ 472.306+ 53184.375 05714.562+ | inches2 feet2 inches2 feet2 inches2 feet2 |

Fundamental Equations

None.

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

None.



17

```
SUBROUTINE PMINER (THI, BLMOM, AREAPT, XMOMIN, XINER)
IF ((TH1 - 0.25000) .EQ. 0.0) GU TO 17
IF ((TH1 - 0.28125) .EQ. 0.0) 60 TO 18
IF ((TH1 - 0.31250) .EQ. 0.0) GU TO 19
IF ((TH1 - 0.34375) .EQ. 0.0) GU TO 20
IF ((TH1 - 0.37500) .EQ. 0.0) GO TO 21
IF ((TH1 - 0.43750) .EQ. 0.0) GO TO 22
IF ((TH1 - 0.50000) .EQ. 0.0) GO TO 23
IF ((TH1 - 0.62500) .EQ. 0.0) GO TO 24
IF ((TH1 - 0.75000) .EQ. 0.0) GO TO 25
IF ((TH1 - 0.87500) .EQ. 0.0) GO TO 26
IF ((TH1 - 0.93750) .EQ. 0.0) GU TO 27
IF ((TH1 - 1.00000) .EQ. 0.0) GO TO 28
8LMOM = 2753.5119629
AREAPT = 188.9225464
XMDMIN = 61274.3710937
XINER = 42284.8554687
RETURN
```

18 BLMOM = 3097.7021484 AREAPT = 212.5378418 XMOMIN = 68933.5

XMUMIN = 68933.5XINER = 47570.0546875

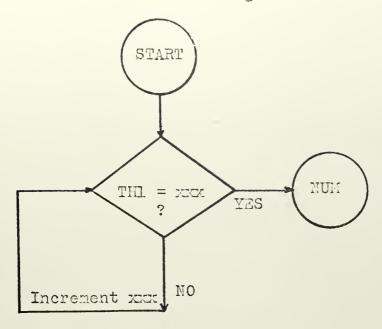
RETURN

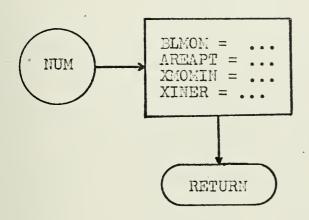
- 19 BLMOM = 3441.895752 AREAPT = 236.1531372 XMOMIN = 76592.5625 XINER = 52854.8671875 RETURN
- 20 BLMOM = 3786.0852051 AREAPT = 259.7683105 XMOMIN = 84251.5625 XINER = 58139.7304687 RETURN
- 21 BLMJM = 4130.2734375 AREAPT = 283.3835449 XMOMIN = 91910.625 XINER = 63424.9726562 RETURN
- 22 BLMOM = 4818.6132812 AREAPT = 330.6142578 XMOMIN =107228.8125 XINER = 73997.5625 RETURN
- 23 BLMOM = 5506.96875 AREAPT = 377.8449707 XMUMIN =122547.25 XINER = 84569.8125 RETURN



- 24 BLMOM = 6863.6835937 AREAPT = 472.3061523 XMOMIN =153184.375 XINER =105714.5625 RETURN
- -25 BLMOM = 8260.421875 AREAPT = 566.7675781 XMUMIN =183821.125 XINER =126857.125 RETURN
- 26 BLMOM = 9637.1679687 AREAPT = 661.2287598 . XMOMIN =214458.25 XINER =148000. RETURN
- 27 BLMJM = 10325.5351562 AREAPT = 708.4592285 XMOMIN =229777.25 XINER =158572.5625 RETURN
- 28 BLMUM = 11013.9257812 AREAPT = 755.6901855 XMUMIN = 245096.0625 XINER = 169143.625 RETURN END







(Tabulated values, to be inserted above)

| xxx | NUM | BLMOM | AREAPT 118.9+ 212.5+ 236.1+ 259.7+ 283.3+ 330.6+ 377.8+ 472.3+ 566.7+ 661.2+ 708.4+ | XMOMIN | XINER |
|----------|-----|----------|-------------------------------------------------------------------------------------|----------|----------|
| 0.25 | 17 | 2753.5+ | | 61274.+ | 4284.+ |
| 0.28125 | 18 | 3097.7+ | | 68933.+ | 47570.+ |
| 0.3125 | 19 | 3441.8+ | | 76592.+ | 52854.+ |
| 0.31:375 | 20 | 3786.0+ | | 84251.+ | 58139.+ |
| 0.375 | 21 | 4130.2+ | | 91910.+ | 63424.+ |
| 0.4375 | 22 | 4818.6+ | | 107228.+ | 73997.+ |
| 0.5 | 23 | 5506.9+ | | 122547.+ | 84569.+ |
| 0.625 | 24 | 6883.6+ | | 153184.+ | 105714.+ |
| 0.75 | 25 | 8260.4+ | | 183821.+ | 126857.+ |
| 0.875 | 26 | 9637.1+ | | 214458.+ | 148000. |
| 0.9375 | 27 | 10325.5+ | | 229777.+ | 158572.+ |
| 0.9375 | 27 | 10325.5+ | 708.4+ | 229777.+ | 158572.+ |
| | 28 | 11013.9+ | 755.6+ | 245096.+ | 169143.+ |

FIGURE IX

SUBROUTINE PHIMER FLOW CHART



H. SUBORDINATE PROGRAM SHDATA

1. DESCRIPTION

Introduction

Program SHDATA generates input data required for main program RUNSCORE (after further manipulation by subroutine PLTGTH). The midship section molded form of DD-931, originally defined by a series of nineteen cubic equations, is defined in detail by a mesh of one hundred ninety-one points by subroutine SHDATA.

Each cubic equation, with one coordinate variable defined in terms of the other, is used to generate ten points on the surface of the midship section shell molded form. The final point defines the shell-plating intersection. The output of this subroutine is then used as an input to program PTLGTH, which calculates the distance between adjacent points.

| <u>Symbol</u> | Meaning | | |
|---------------|-------------------------|-------|----|
| COORD1 | The dependent variable. | (Y or | Z) |

^{*}Provided by courtesy of Mr. Lee Mount of J. J. Henry Co., Inc.



| • | Symbol | Mean | ning |
|------------|------------------|---------------------------------------------------------------|-----------------------------------------------------------------------------------|
| | COORD2 | The ind Y) | dependent variable. (Z or |
| | NOSEG . | The nur | aber of the cubic equation. |
| | PTHIN | Minimur | n value of the independent riable. (Feet) |
| | PTMAX | Maximum | n value of the independent riable. (Feet) |
| | AA | Fixed o | quantity in the cubic |
| | BB | Coeffic | lation. |
| | CC | Coeffic | dependent variable. |
| | DD | Coeffic | dependent variable. cient of the third power dependent variable. |
| • | | | |
| Calculated | d Items | | |
| | Symbol | Mean | ning |
| | $\Lambda\Lambda$ | The inc | dependent variable. (Feet) |
| | SUM | The de | pendent variable. (Feet) |
| | DIFF | | of the independent variable. |
| | | (P) | ee() |
| Output | | | |
| | Symbol | Mea | ning |
| | EE | Half b | readth of point. (Feet) |
| | FF . | Height (F | of point above base line. eet) |
| Sample In | put/Output | (Computer | test run) |
| | Input: | COORDI COORD2 NOSEG PTMIN PTMAX AA BB CC | Z Y 1 0.0 Feet 2.0 Feet 0.0000 0.023692 0.0000 0.00058957 |



| Output: | Segment | Point | Y | Z |
|---------|---------|-------|----------|----------|
| • | I | 1 | 0.00 | 0.000000 |
| | 1 | 2 | 0.20 | 0.004743 |
| | 1 | 3 | O•#O | 0.009515 |
| | 1 | 4 | 0.60 | 0.014343 |
| | 1 | 5 | 0.80 | 0.019255 |
| | 1 | 6 | 1.00 | 0.024282 |
| | 1 | 7 | 1.20 | 0.029449 |
| | 1 | 8 | 1.40 | 0.034787 |
| | 1 | 9 | 1.599999 | 0.040322 |
| | 1 | 10 | 1.799999 | 0.046084 |

Fundamental Equations

$$SUM = AA + BB \times VV + CC \times VV^2 + DD \times VV^3$$

VV = VV + STEP

STEP = DIFF / 10.

DIFF = PTMAX - PTMIN

Sample Calculation (Refer to subordinate program listing and flow chart, following pages)

DIFF = PIMAX - PIMIN

= . 2.0

STEP = 2.0 / 10. = 0.20

VV = 0.20

SUM = $0.023692 \times VV + 0.00058957 \times VV^3$ = 0.004743



```
_____ 127 ____
LEVEL 02 NOV. 66
                                                     JS/350 FORTMAN H
           COMPLLER DATIONS - NAME = MAIN, OPT = 00, LINEON 1 = >0, SOURCE, ECD, NOLIST, OF
   IS4 0002
                    901 FORMAT (2A1, 13, (F10.5)
                   POS FORFAT TIECTALLISH A FORCTION OF TALFOR SEGMENT FIST MAIRST
  ISV DOUS
                    114H X= 295.500000.3H Y=.F10.6,3H Z=, F10.5)
903 READ (5,981) COURDI,COURDZ, NUSEG, PTMIN, PTMAX, AA, B5, CC, DD
   ISH 0004
                        OIFF = PIMAX - PIMIN
  ISM 0005
   ISN 0006
                        Site = DIFF / 10.
   IS4 0007
                        VV = PININ
   ISN COOR
                        DO 907 I = 1, 10
   ISM DCD9
                        SUM = AA & CB*VV & CC*(VV**2) & DD*(VV**3)
   ISN DOLO
                        IF (NOSEG .GT. 7) GP TO 905
   ISM 0012
                        EE = SU4
                        FF = VV
   IS 1 0013
   ISN 0014
                        GO TH 906
                    GOSTESTETVV
   ISN GC15
   ISN 0016
                        FF = SUM
   ISN DOIT
                    FOR WRITE (5,402) COURDI, COURDZ, NOSEG, T, FF, EF
                   904 WRITE (7,902) CUORDI, CDORD2, MOSEG, I, FF. FE
   ISN 0618
   ISN 0019
                    907 VV = VV & SIFP
   ISN 0020
                        IF ((NOSEG - 20) .EC. 0) 60 TO 917
   13N 0022
                        G0 10 913
   ISN 0023
                    917 STOP
   ISN 0024
                        E41)
```



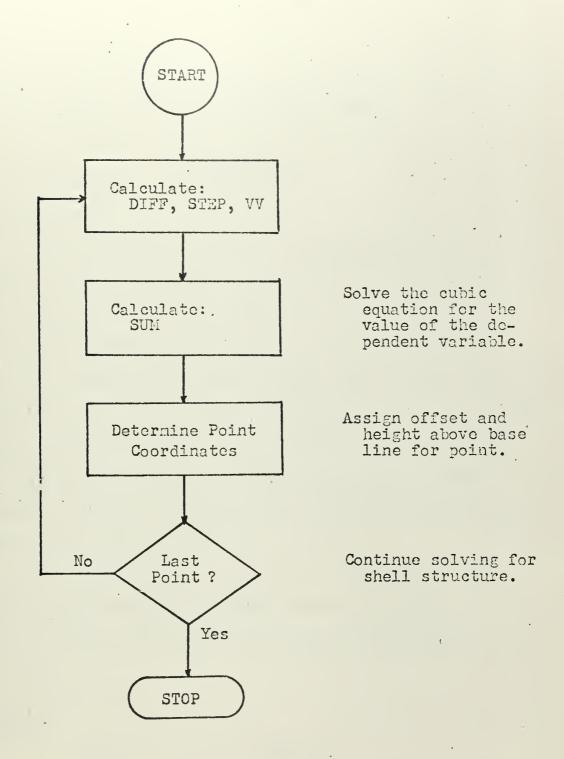


FIGURE X
SUBORDINATE PROGRAM SHDATA FLOW CHART



I. SUBORDINATE PROGRAM DEDATA

1. DESCRIPTION

Introduction

Program DKDATA is designed to generate a series of points on the molded deck of the midship section of DD-931. The half breadths of the points are determined on the basis of the angle of the sine function used to define the height of the camber curve. For the deck edge, the sine equals zero, while the value is one at the centerline. A direct correlation between the angle involved and the half breadth is maintained—if the angle is forty-five degrees, the point defined exists at exactly half the maximum breadth of the molded deck plating.

One hundred points are defined, equivalent to ten cubic segments with ten points evaluated on each, as in program SHDATA. One added point defines the centerline of the deck.

| Symbol | Meaning |
|--------|---------------------------------------------------------|
| COORDI | The dependent variable. (2) |
| COORD2 | The independent variable. (Y) |
| ZMIN | The height of the deck edge above the base line. (Feet) |



Symbol Meaning

ZHAX The height of the deck centerline above the base line. (Feet)

YMAX The half breadth of the deck edge.

(Feet)

Calculated Items

Symbol Meaning

STEP Angular increment for the sine

function. (Radians)

Increment of the halfbreadth YYY for adjacent points. (Feet)

FF/YBEG Offsets of the point. (Feet)

DIFF Height difference between the

deck edge and the deck center-

(Feet) line.

"Segment" number -- for uniformity NOSEG

with SHDATA output.

"Point" number within the segment. I

ANGLE Angle to be used for the camber

calculation of the height of

the deck. (Radians)

Cutput

Symbol Meaning

Offsets to the point. (Feet) FF

EE Height of the point above the

base line. (Feet)

(Computer test run) Sample Input/Output

> COORD1 \mathbf{Z} Input: Y COORD2

25.239594 26.231247 ZHIN Feet ZMAX Feet 22.343796 YIJAX Feet



| Output: | Segment | Point | Y | Z |
|---------|---------|-------|-----------|-----------|
| | 20 | ·l | 22.343796 | 25.239594 |
| | 20 | 2 | 22.120346 | 25.255157 |
| | 20 | 3. | 21.896896 | 25.270737 |
| | 30 | ĭ | -0.000348 | 26.231247 |

Fundamental Equations

STEP = THETA / 100.

YYY = YMAX / 100.

YBEG = YMAX, later = YBEG - YYY

DIFF = ZMAX - ZMIN

ANGLE = ANGLE + STEP

 $EE = ZMIN + DIFF \times SIN(ANGLE)$

FF = YBEG

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

STEP = 0.015708

YYY = 0.22343796

 $YBEG = 22.3^{1}+3796$

DIFF = 0.991653

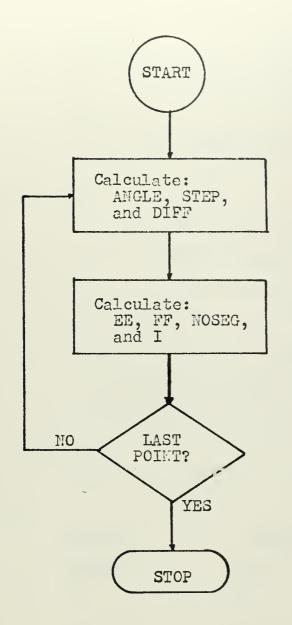
 $EE = 25.239594 + 0.991653 \times Sin (0.)$ = 25.239594

FF = 22.343796



```
COMPILER OFFICES - NAME = MAIN, OPI = 00, LINECHT = 50, SOURCE, BCD, NOLIST, DE
                901 FORMAT (2A1,3F10.5)
ISN 0002
ISN 0003
               902 FORMAT (1HO, A1, 15H A FUNCTION OF , A1, 9H SEGMENT , 12, 7H P3
                   114H X= 203.500000,3H Y=,F10.6,3H Z=, F10.6)
ISN 0004
                903 READ (5,901) COORDI, COORDZ, ZMIN, ZMAX, YMAX
ISN 0005
                    THETA = 0.5 \div 3.1415927
ISN 0006
                    STEP = THETA / 100.
ISN 0007
                    FF = 0.0
ISN 0008
                    DIFF = ZMAX - ZMIN
ISN 0009
                    ANGLE = 0.0
ISN 0010
                    YYY = YMAX / 100.
ISN 0011
                    YBEG = YMAX
ISN 0012
                    AA = 0.05
ISN 0013
                    00 907 J = 1, 101
ISN 0014
                    FF = YBEG
ISN 0015
                    EE = ZMIN & DIFF * SIN(ANGLE)
ISN 0016
                    NOSEG = AA
ISN 0017
                    K = AA
                    \Delta K = K
ISN 0018
ISN 0019
                    I = 10.0 * (AA & 0.1) - 10.0 * AK
ISN 0020
                    IF (I .EQ. 0) GO TO 910
ISN 0022
                    GO TO 909
               910 I = 10
ISN 0023
ISN 0024
               909 AA = AA & O.1
ISN 0025
                    NOSEG = NOSEG & 20
ISN 0026
               904 WRITE (6,902) COORDI, COORDZ, NOSEG, I, FF, EE
ISN 0027
               905 WRITE (7,902) COORD1, COORD2, NOSEG, I, FF, EE
ISN 0028
                    YBEG = YBEG - YYY
ISN 0029
               907 ANGLE = ANGLE & STEP
ISN 0030
                    STOP
ISN 0031
                    END
```





Determine the initial angle and the increments of the angles and offsets.

Determine the point coordinates.

FIGURE XI
SUBORDINATE PROGRAM DKDATA FLOW CHART



J. SUBORDINATE PROGRAM PILGTH

1. DESCRIPTION

Introduction

Program PTLGTH uses the outputs of SHDATA and DKDATA to calculate the distance between adjacent points, based on the assumption that the distance between two points can be closely approximated by a straight line segment. In view of the short distances involved, this results in a relatively precise calculation. The center of gravity of the short segment so defined is evaluated by linear interpolation.

| Symbol | <u>Meaning</u> |
|--------|-----------------------------------------------------|
| NOSEGI | Segment number of initial point. |
| Il | Point number of initial point. |
| YPTl | Half breadth of initial point. (Feet) |
| ZPTl | Height of initial point above |
| NOSEG2 | base line. (Feet) Segment number of next point. |
| 12 | Point number of next point. |
| YPT2 | Half breadth of next point. |
| ZPT2 | (Feet) Height of next point above base line. (Feet) |



Outout

| <u>Symbol</u> | <u>Meaning</u> |
|---------------|-----------------------------------------------------|
| DIST | Distance from initial to next point. (Feet) |
| ZCGPT | Height of mid point of DIST above base line. (Feet) |

Sample Input/Output (Computer test run)

| Input: | NOSEG1 I1 YPT1 ZPT1 NOSEG2 I2 YPT2 ZPT2 | 1 0.0 0.0 0.0 1 2 0.200000 0.00 ¹ +7 ¹ +3 | Feet Feet Feet |
|---------|-----------------------------------------|--------------------------------------------------------------------------------------|----------------------|
| Output: | DIST ZCGPT | 0.200056 | Feet Feet |

Fundamental Equations

DIST =
$$\sqrt{(YPT2 - YPT1)^2 + (ZPT2 - ZPT1)^2}$$

ZCGPT = 0.5 x (ZPT1 + ZPT2)

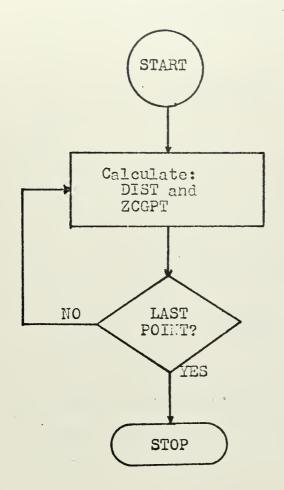
Sample Calculation (Refer to subroutine listing and flow chart, following pages)

DIST =
$$\sqrt{(0.20000)^2 + (0.004743)^2}$$

= $\frac{0.200056}{0.004743}$
ZCGPT = $0.5 \times (0.004743)$
= $\frac{0.002371}{0.002371}$







Determine the distance between two points and the height of the mid-point above the base line.

FIGURE XII

SUBORDINATE PROGRAM PILGIH FLOW CHART



K. SUBORDINATE PROGRAM WISHOD

1. DESCRIPTION

Introduction

Subordinate program WTSMOD calculates the total girth, plating weight, moment of inertia, and location of the neutral axis for the midship section plating.

The calculation of the section modulus is based on the following equation: [2]

XMDIZ = 2.0 x BLMOM² - (AREAPT x XMOMIN)
BLMOM - AREAPT x ZCOORD

The output of PTLGTH is used as an input to WTSNOD. Each small segment between points on the girth is treated as a rectangular segment with a width equal to the specified thickness of the plating. The component values used in the calculation of the section modulus are stored in Subroutine PMINER for eventual use in Main Program RUM-SCORE.

| Symbol | Meaning |
|---------------|-------------------------------------------------|
| PTDATA(I,J,1) | Half-breadth of point (I,J). (Feet) |
| PTDATA(I,J,2) | Height of point (I,J) above base line. (Feet) |
| PTDATA(I,J,3) | Distance from point (I,J) to next point. (Feet) |



Meaning

Symbol

XMD1K

XIDID

ZNAX

XINER

PTDATA(I,J,4) Height of midpoint of PTDATA (I,J,3) above base line. (Feet) WPERIN Weight of the structural material. (Pounds per inch thickness of a one square foot plate) THL Plating thickness. (Inches) Calculated Items Meaning Symbol GIRTH Total distance between points for the half breadth. (Feet) Intermediate value used in cal-AA culating MOMIN. BB Intermediate value used in calculating XMOMIN. Output Symbol Meaning WIPRFI Total weight of the plating. (Pounds or Tons per foot) Total circumference of the GIRX2 midship section plating. (Feet) Moment of the plating about the base line. (In.2 Feet) BLMOM Cross-sectional area of the plating. (In.2)
Moment of inertia of the plating AREAPT XMOMIN about the base line. (In. Section modulus at the keel.

(In.2 Feet)

Section modulus at the deck. (In. Feet)

base line. (Feet)

Height of the center of gravity of the plating above the

Moment of inertia of the plating about ZNAX. (In. 2 Ft. 2)



Sample Input/Output (Computer test run)

Fundamontal Equations

GIRTH = GIRTH + PTDATA(I,J,3)

WTPRFT = 2.0 x GIRTH x WPERIN x THL

 $GIRX2 = 2.0 \times GIRTH$

 $AA = 0.08333 \times THL \times PTDATA(I,J,3)$

 $BB = TH1^{2} \times \left(\frac{PTDATA(I+1,1,1,) - PTDATA(I,J,1)}{PTDATA(I,J,3)}\right)^{2} + 144. \times (PTDATA(I+1,1,2) - PTDATA(I,J,2))^{2}$

BLMOM = BLMOM +

12. \times TH1 \times PTDATA(I,J,3) \times PTDATA(I,J,4)

AREAPT = 12. x GIRTH x THL

 $XMOMIN = XMOMIN + 0.0833 \times AA \times BB +$

12. x THL x PTDATA(I,J,3) x PTDATA(I,J,4) 2

GMDLK = 2.0 x $\left(\frac{\text{PLMOM}^2 - \text{AREAPT x XMOMIN}}{\text{BLMOM}}\right)$



$$\text{XMODID} = 2.0 \times \frac{\text{BLMOM}^2 - \text{ARRAPT } \times \text{XMOMIN}}{\text{BLIJOM} - 25.23125} \times \text{ARRAPT}$$

 $ZNAX = \frac{BLIOM}{AREAPT}$

XINER = XMD1K x ZNAX

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

XINER =
$$\frac{1}{12}$$
 x $\frac{1}{4}$ x 20 x $\left[\frac{1}{192}$ x $\left(\frac{3}{5}\right)^2$ + $\frac{2}{192}$ x $\left(\frac{4}{5}\right)^2$ = $\frac{2,560}{192}$ in. 2 ft. 2



```
COMPILER OPTIONS - NAME - MAIN, OPF=00, LINECHT=50, SOURCE, BCD, NOLIST, DECK, LOAD, M
              DIMENSION PIDATA (30,10,4)
002
          900 FORMAT (2F20.7)
003
          901 FORMAT (23X, 4(2X, F10.6))
004
              D0 907 I = 1, 29
005
005
              DO 907 J=1, 10
              READ (5, 901) PIDATA (I,J,1), PIDATA(I,J,2), PIDATA(I,J,3),
007
             1 PTDATA(I,J,4)
008
          907 CONTINUE
009
              I = 30
              J = 1
010
              READ (5, 901) PTDATA(I, J, 1), PTDATA(I, J, 2), PTDATA(I, J, 3),
011
             1 PTDATA(I,J,4)
              00 910 J = 2, 10
012
              D0 910 K = 1, 4
013
          910 PIDATA (I, J, K) = 0.0
014
015
          888 READ (5,900) WPERIN, THI
016
              IF ((WPERIN - 100.) .GT. 0) GO TO 999
           84 FORMAT ('1 PLATING THICKNESS = ', F10.6, ' INCHES')
018
019
           85 FORMAT (' WEIGHT =',F10.6,' POUNDS PER SQ. FT. PER INCH THICKNES
            151)
020
              WRITE (6, 84) TH1
              GIRTH = 0.0
021
              00 800 I = 1, 30
022
023
              DO 800 J = 1, 10
          800 GIRTH = GIRTH & PTDATA(I,J,3)
024
025
              WTPRET = 2.0 * GIRTH * WPERIN * THI
          801 FORMAT ('O PLATING WEIGHT = ', F20.7, ' POUNDS PER FOOT')
026
          802 FORMAT (' PLATING WEIGHT =', F20.7, ' TONS PER FOOT')
027
          803 FORMAT ('9 FOTAL MIDSHIP SECTION GIRTH =',F15.7,' FEET')
028
029
              GIRX2 = 2.0 * GIRTH
030
              WRITE (6,803) GIRX2
              WRITE (6,801) WTPRFT
031
032
              WTPRFT = WIPRFT / 2240.
033
              WRITE (6, 802) WTPRFT
034
              WRITE (6,85) WPERIN
035
              BLMOM = 0.0
              AREAPT = GIRTH * TH1 * 12.0
036
037
              DO 400 I = 1, 29
038
              00 400 J = 1, 10
039
          400 BLMOM = BLMOM & 12. * TH1 * PTDATA(I,J,3) * PTDATA (I,J,4)
040
              0.0 = NIMOMX
041
              00\ 500\ I = 1,\ 29
042
              D0 500 J = 1, 10
043
              AA = 0.083333 * TH1 * PTDATA (I, J, 3)
              IF ((J - 10) .NE. 0) GO TO 501
044
              BB = (TH1**2)*((PTDATA(I&1,1,1)-PTDATA(I,J,1))/PTDATA(I,J,3))**2 &
046
             1 ((PTDATA(I&1,1,2) - PTDATA(I,J,2))**2) * 144.
047
              GO TU 600
          501 BB = (TH1**2)*((PTDATA(I,J&I,I) - PTDATA(I,J,I))/PTDATA(I,J,3))**2
048
```



```
1 & 144. * (PTDATA(I, J81, 2) - PTDATA(I, J, 2))**2
          600 XMOMIN = 0.08333*AA*BB & XHOMIN & 12.* PTDATA(1, J, 3)*TH1*PTDATA
049
             1([, J, 4) ##2
1050
          500 CONFINUE
              XMD1K = 2.0 * (((3LM04**2) - (AREAPT * XMOMIN)) / BLMOM)
051
              XMDID = (((BLMOH**2) - (AREAPI*XMOMIN)) /(BLMOM - 26.231247
052
             1 * AREAPT)) * 2.0
053
          304 FORMAT ('O SECTION MODULUS--KEEL =',F20.7,' INCHES**2 FEET')
          305 FORMAT ('O SECTION MUDULUS--DECK =',F20.7,' INCHES**2 FEET')
054
          307 FURMAT ( 10 MOMENT OF INERTIA IS', F20.7, INCHES**2 FEET**2')
055
              ZNAX = BLMOM / AREAPT
055
              XINER = XMDIK * ZNAX
057
053
              WRITE (6,307) XINER
          306 FORMAT ('O NEUTRAL AXIS IS', F20.7, FEET ABOVE BASE LINE')
059
          401 FORMAT ('0 BLMOM = 1, F20.7, FT IN**21)
060
          402 FORMAT ('0 AREAPT =', F20.7, ' IN**2')
061
062
          403 FURMAT ('0 XMUMIN = 1, F20.7, 1 FT**2 IN**2")
063
              WRITE (6,401) BLMOM
064
              WRITE (6,402) AREAPT
065
              WRITE (6,403) XMOMIN
              WRITE (6,306) ZNAX
066
              WRITE (6, 304) XMD1K
067
              WRITE (6, 305) XMD1D
068
              GO TO 888
069
070
          999 STOP
071
              END
```



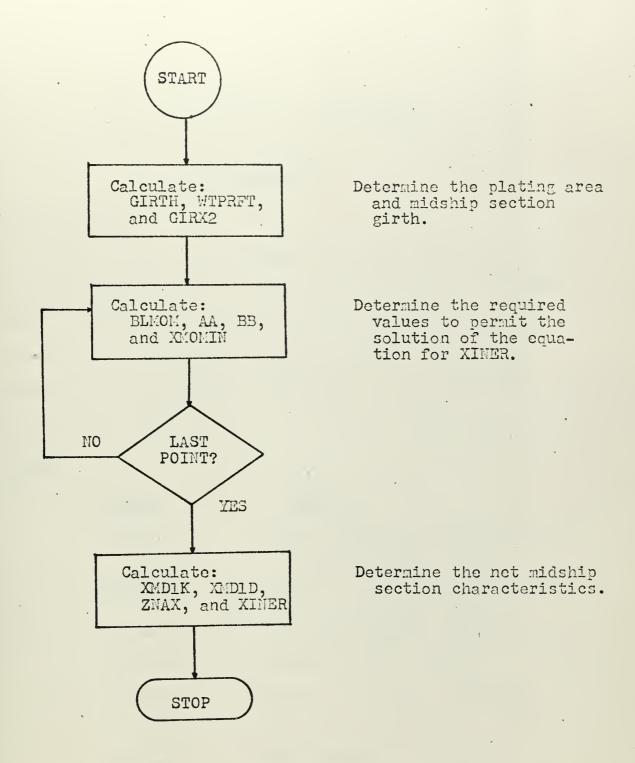


FIGURE XIII
SUBORDINATE PROGRAM WISHOD FLOW CHART



L. SUBORDINATE PROGRAM TSHAPE

1. DESCRIPTION

Introduction

Subordinate program TSHAPE calculates the structural characteristics of wide flange sections cut to a T-section. For the purposes of calculating the maximum and minimum moments of inertia and the cross-sectional area, it is assumed that the flange is cut off at a distance 0.125 inches from the web.

Inputs

| Symbol | Meaning |
|-----------|-------------------------------------------------------------------------------------------------------|
| SMAXI(I) | Maximum moment of inertia of the original member, about its |
| SMINI(I) | neutral axis. (In.4) Minimum moment of inertia of the original member, about its neutral axis. (In.4) |
| SAREA(I) | Cross-sectional area of the ori- ginal member. (In.2) |
| SFLGW(I) | Flange width. (Inches) |
| SFLGTH(I) | Flange thickness. (Inches) |
| SDEPTH(I) | Web depth. (Inches) |
| SWEBTH(I) | Web thickness. (Inches) |
| SCOST(I) | Acquisition cost. (Dollars/Foot length) |



Calculated Items

| Symbol | Heaning |
|-----------|-----------------------------------------------------------------------------|
| SM | Moment of the cut member about the cut flange. (In.3) |
| SA | Cross-sectional area of the cut member. (In.2) |
| SI | Moment of inertia of the cut member about the cut flange. (In. ') |
| SMAXI(I) | Maximum moment of inertia of the cut member, about its neutral axis. (In.4) |
| SMINI(I) | Minimum moment of inertia of the cut member, about its neutral axis. (In.") |
| SAREA(I) | Cross-sectional area of the cut member. (In.2) |
| SFLGW(I) | Flange width. (Inches) |
| SFLGTH(I) | Flange thickness. (Inches) |
| SDEPTH(I) | Web depth. (Inches) |
| SWEBTH(I) | Web thickness. (Inches) |
| SCOST(I) | Acquisition cost. (Dollars/ |
| VCG(I) | Foot length) Distance of the neutral axis from the cut flange. (Inches) |

Sample Input/Cutput (Computer test run)

| Input: | SMAXI(1) SMINI(1) SAREA(1) SFLGW(1) SFLGTH(1) SDEPTH(1) SWEBTH(1) SCOST(1) | 21.70 2.89 3.53 4.00 0.279 6.00 0.23 2.00 | In.4 In.2 In. In. In. In. Dollars/Foot |
|---------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------|--------------------------------------------|
| Output: | SMAXI(1) SMINI(1) SAREA(1) SFLGW(1) SFLGTH(1) SDEPTH(1) SWEBTH(1) SCOST(1) VCG(1) | 10.56 1.40 2.55 4.00 0.279 6.00 0.23 2.00 4.10 | In.4 In.2 In. In. In. In. Dollars/Foot In. |



Fundamental Equations

Sample Calculation

$$VCG(1) = \frac{0.5 \times 6. \times 3.53 - 0.5 \times .279^{2} \times 3.52}{3.53 - 0.279 \times 3.52}$$
$$= 4.10$$

SMAXI(1) = 21.70 - 0.1667 x 1.76 x 0.279³ - (0.279 x 3.52) x (3.0 - 0.1395)² =
$$\frac{10.56}{}$$

SMINI(I) =
$$2.89 - 0.1667 \times 0.279 \times 1.76^3 - (0.279 \times 3.52) \times 1.12^2 = 1.40$$

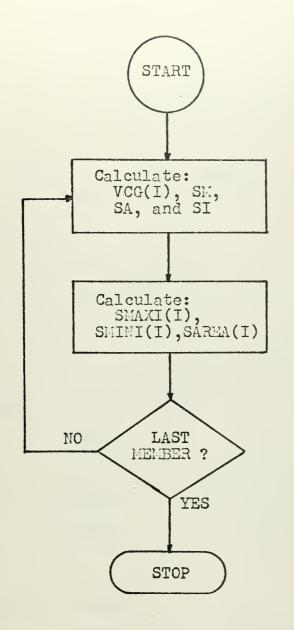


US/360 FORTRAN 4

12 NUV. 55

```
COMPILER OPTIONS - WIME= MAIN, JPT=00, LINECHT=50, SOURCE, BCD, NOLIST, DECK, LOAD
                DI MENSION SMAXI(9), SMINI(9), SAKEA(9), SFLGH(9), SFLGTH(9), SDEPTH(9)
0002
               1- S-ESTH(9), VCG(9), SCDST(9)
0003
            400 FURHAT (8F10.5)
            401 FORMAT (181,3x, "MAX. INERTIA", 3x, "MIN. INERTIA", 7x, "AREA", 7x,
-0004
               1 'FLANGE WIDTH', 4x, 'THICKNESS', 6x, 1, EB DEPTH', 6x, 'THICKNESS',
              -2-9x, 'COST') ...
            402 FORMAT (1x,2(3x,' IN##4 '),4x,'SQ. INCHES',7x,'INCHES',
0005
             -- 1 3(9x, '[NCHES'], 7x, 'DOLLARS/ET.')
0005
                ARITE (0,401)
2007-
               -ARITE (5,402)
0008
                DO 403 I=1,9
                READ (5,400) SMAXI(I), SMINI(I), SAREA(I), SFLGH(I), SFLGH(I), SDEPTH
0009
               1 (I), SWESTH(I), SCUST(I)
CC10-
            403 CONTINUE _
            404 FURMAT (1HC, 4%, F10.5, 7(5X, F10.5))
0011
0012
             0013
                WKITE (6,404) SMAXI(I), SMINI(I), SAREA(I), SFLGW(I), SFLGTH(I),
              _L_SDEPIH(I), SWEBIH(I), SCOST(I)_____
            405 CUNTINUE
0014
0015
              10 406 I = 1,2
                VCG(I) = ((0.5 * SDEPIH(I) * SAREA(I)) - (0.5 * (SFLGTH(I)**2) *
0016
               L(SELGW(I)-0.25-SWEBTH(I)))/(SAREA(I)-((SFLGW(I)-0.25-SWEBTH(I)))*
               2 SFLGTH(I)))
2017
               __SA_=_SAREALIJ*(U.5*SDEPTH(I))=0.5*(SELGTH(I)**2)*(SFLGW(I)-0.25-
               1 SAESTH(I)
0018
              __SA_ =_SAREA(I) = _(SFLGW(I) = _0.25 =_SWEBTH(I))*SFLGTH(I)
               SI = SMAXI(I) & SAREA(I)*(0.5*SDEPTH(I))**2 - 0.0833*(SFL3W(I) -
0019
               1-0.25 - SMEBTH([]) * (SFLCTH([) **3) - (SAREA([) -SA) * (0.5 + SFLGTH([))
               2 **2
0020
               SHAXI(1) = VCG(1) * (4(SA * SI) - (SM**2)) / SH ) -
0021
                SMINI(I) = SMINI(I) - 0.16657*SFLGTH(I) * (0.5 * (SFLGN(I) - 0.25-
               1-SWFBTH(I1))**3 -- (SAREA(I) -- SA) * (0.1258 0.5*SWEBTH(I) & 0.25 4
               2 (SFLGW(I) - 0.25 - SWEBTH(I)))**2
              __SAREA(I) = SAREA(I) - (SFLGN(I) - 0.25 -SNEBTH(I)) * SFLGTH(I)
0022
0023
           406 CUNTINUE
4024
               WRITE (6,401)
0025
                ARITE (5,402)
0026
           411 FORMAT (15x, '_ SHAPE VCG IS ', E10.7, ' INCHES FROM EDGE OF CUT FLAN
              1 SE 1)
2627
               DD 4.0/ I=1.9....
0028
                WRITE (6,404) SMAXI(I), SMINI(I), SAREA(I), SFLGW(I), SFLGTH(I),
             _1_SDEPTH(I), SWEBIH(I), SCOST(I)
0029
                WRITE (6,411) VCG(I)
0030
           407 CUNTINUE
0031
                STOP
0032
                END
```





Determine the cut shape VCG and preliminary values for computing SMAXI(I).

Determine the net cut section area and moments of inertia.

FIGURE XIV
SUBORDINATE PROGRAM TSHAPE FLOW CHART



M. SUBORDINATE SUBROUTINE COSTKL

1. DESCRIPTION

Introduction

Subordinate subroutine COSTKL is used to generate the total cost per foot length of the keel structure. The methodology and values used are explained at length in the description of main program COSTDATA.

Inputs

| Symbol | <u>Meaning</u> |
|--------|----------------------------------------------------------------|
| CKLGTL | Acquisition cost of the keel lor- gitudinal. (Dollars/Foot) |
| CHC:NH | The cost of one man-hour of work. (Dollars) |
| FKTHCK | Thickness of the flanges of the keel longitudinal. (Inches) |

Calculated Items

| PAUDOT | <u>reaning</u> |
|--------|-----------------------------------|
| CCUTF | Cost of cutting the keel flanges. |
| | (Dollars/Foot) |
| CWELD | Cost of welding the keel. |
| | (Dollars/Foot) |

Output

| Symbol | Meaning | |
|--------|-------------------------------------------------|---|
| CKEEL | Total cost of the keel structure (Dollars/Foot) | • |



Sample Input/Output (Computer test run)

Input: CKLGTL 9.00 Dollars/Foot

7.50 0.468 CHGMNH Dollars/Hour

Inches FKTHCK

27.56 Output: CKEEL Dollars/Foot

Fundamental Equations

 $CCUTF = 0.2 \times CHGMMH$

 $CWELD = 2.2748 \times CHGMNH$

Sample Calculation (Refer to program listing and flow chart, following pages)

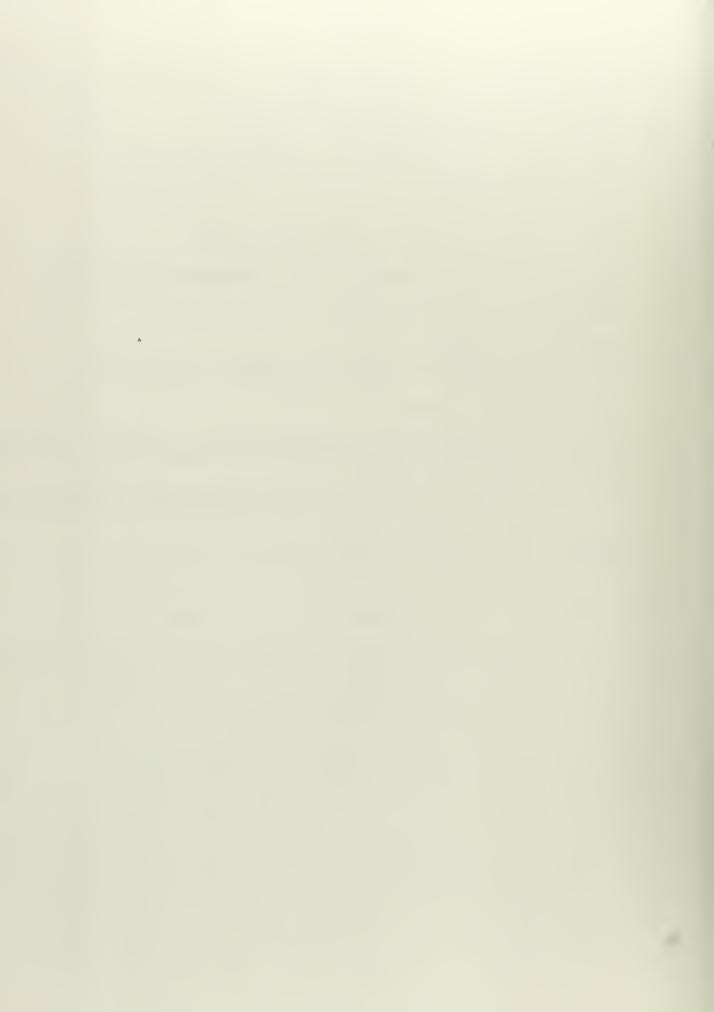
CCUTF = 1.50

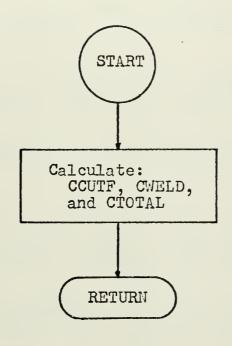
CWELD = 17.06

CKEEL = 27.56



```
777 EORMAT (3E20.6)
      READ (5,777) CKLGTL, FKTHCK, CHGMNH
      CALL COSTKL (CKLGTL, FKTHCK, CHGMNH, CKEEL)
  778 FORMAT ('1 ACQUISITION COST =', F10.6)
  779 FORMAT (10 CHARGE PER MANHOUR =1, F10.6)
  780 FORMAT ('0 TOTAL KEEL COST = 1, F10.6)
      WRITE (6,778) CKLGTL
      WRITE (6,779) CHGMNH
      WRITE (6,780) CKEEL
      STOP
      END
      SUBROUTINE COSTKL (CKLGTL, FKTHCK, CHGMNH, CKEEL)
C
      CALCULATE THE TOTAL COST CONTRIBUTION OF THE KEEL STRUCTURE.
C
      FIRST, CALCULATE THE COST OF CUTTING THE FLANGES.
C
      CCUTF = 0.2 * CHGMNH
C
      CALCULATE THE COST OF WELDING THE SHAPE TO THE PLATING.
C
      CWELD = 2.2748 * CHGMNH
      THE MAN HOUR CHARGES ALLOW FOR MAKE READY AND PUT AWAY, THE WELDING
C
      ITSELF, THE CONTINUOUS JOB ALLOWANCE, WIRE BRUSHING, ARC AIR, DYE
C
      PENETRANT, AND STRIP HEATER.
C
      CALCULATE THE TOTAL COST--ACQUISITION, PREPARATION, AND INSTALLATION.
C
C_
      CKEEL = CKLGTL + CCUTF + CWELD
      RETURN
      END
1*
//G.SYSIN DD
                                                 7.50
        9.00
                            0.775
```





Determine the cost of the keel member, per foot length.

FIGURE XV
SUBORDINATE SUBROUTINE COSTKL FLOW CHART



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